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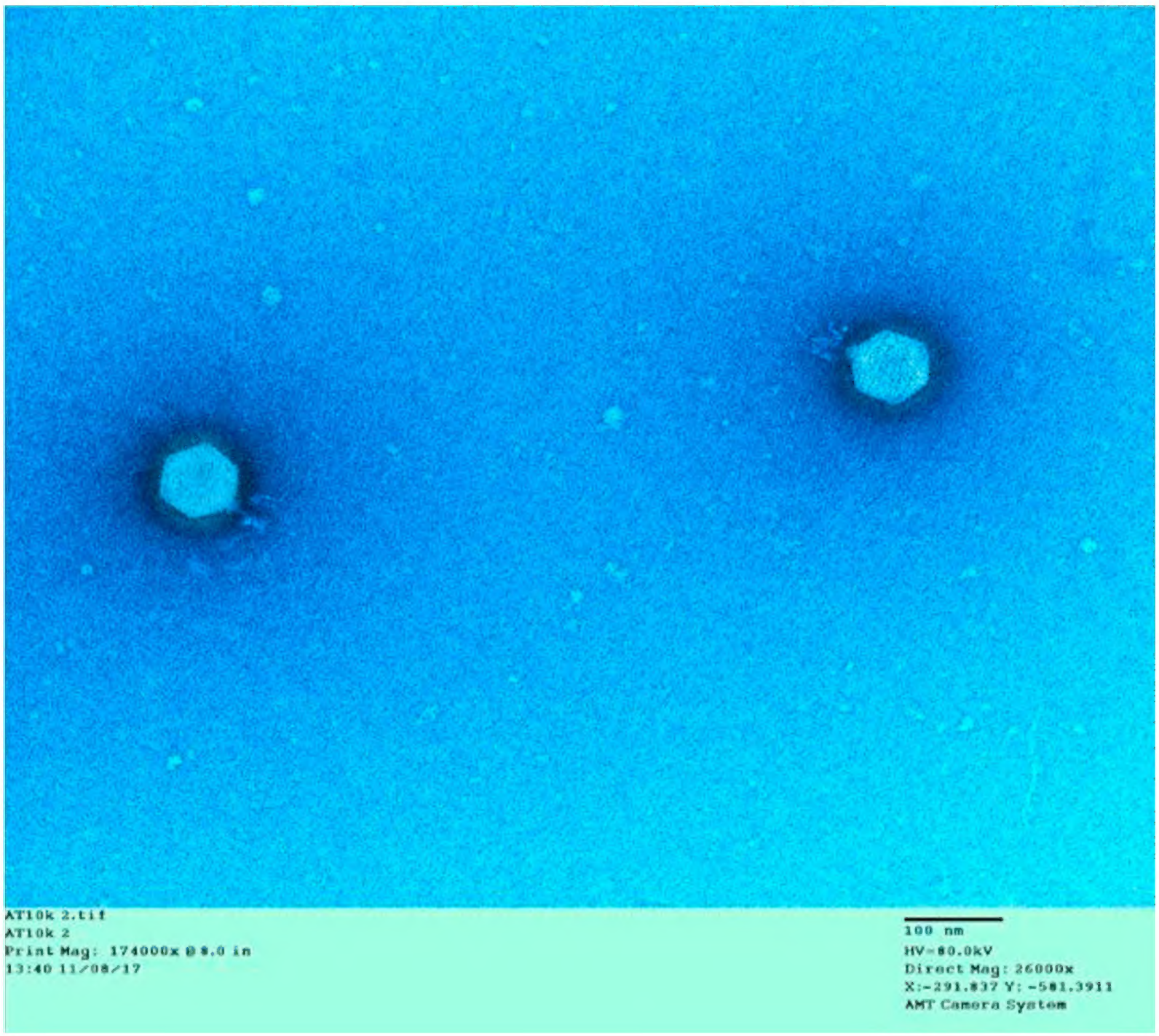

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Cover Photograph: Electron micrograph of LY218, a bacteriophage of Pseudomonas aeruginosa. ATCC 27853. Photograph credit: Benjie Blair, Ashraf Amshaqn, and Chris Murdock from their work in the first article in this issue of the journal.

Editorial Comment:
On behalf of the Alabama Academy of Science, I would like to express my gratitude and appreciation to the reviewers for their valuable contributions in reviewing the manuscripts of this issue.

Thanks!
Brian Toone
Editor: Alabama Academy of Science Journal

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IN MEMORIAM

Dr. Benjamin (Benjie) Blair
Professor of Biology at Jacksonville State University

Dr. Benjamin (Benjie) Blair, Professor of Biology at Jacksonville State University is a co-author of the first two articles in this issue of the Journal of the Alabama Academy of Science. These articles are being published posthumously as Dr. Benjie Blair passed away on October 20, 2020.

Read more about this amazing man's life and legacy here: https://asm.org/Obituaries/In-Memoriam-Blair,-Benjamin-Benjie

Journal of Alabama Academy of Science, Vol. 91, No. 2, November 2020

ISOLATION, CHARACTERIZATION AND COMPLETE GENOME SEQUENCE OF LY218: A BACTERIOPHAGE OF *Pseudomonas aeruginosa* ATCC 27853.

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ABSTRACT

It has become widely accepted that bacteriophages are extremely abundant and are enormously influential on the biosphere. Bacteriophages kill between 4-50% of the entire bacteria population daily (Suttle, 2005). The aim of this study was to screen soil samples for *Pseudomonas aeruginosa* lytic phages, select and characterize an isolate morphologically for genome analysis using next generation lllumina sequencing. The lytic isolate was detected using the spot method on lawns of *P. aeruginosa*. Using the described procedure (Jordan, et al. 2010), LY218 was successfully isolated from soil samples. Transmission electron microscopy (TEM) performed by the University of Alabama at Birmingham (UAB), High Resolution Imaging Facility (HRIF) and Illumina Next Generation Sequencing (NGS) also at UAB, were performed to determine the morphology of the phage. The TEM images reveal that this isolate has a short tail when compared to other *Myoviridae* phages. Upon performing the Blast NCBI sequence comparison analysis, it was determined that this isolate is 73083 bp and it is 97% identical to the *Pseudomonas* phage Phi176, a phage isolated and sequenced in Bath, England. Phi176, was submitted to the GenBank database with accession number KM411960. A total of 88 presumptive genes have been identified. Presumptive function of 86 proteins were called based on homology determined by Predict Protein. The 3% difference between these two phage sequences is centered on two proteins of indeterminant function. Sequencing of the LY218 genome revealed a dsDNA with 54.9% G+C content and 356 open reading frames (ORFs) were predicted to be coding sequences. The full nucleotide sequence of the genome of LY218 has been determined, and this has been deposited (the NCBI accession number in MN906996).

INTRODUCTION

After returning to France in 1915, the Franco-Canadian microbiologist Félix d'Herelle noticed some mysterious clear spots within his cultures of coccobacilli which he concluded were zones of dead bacteria (Keen, 2012) and (Fruciano, 2007). It was d'Herelle who first used the term *plaque* to describe the circular area of clearing caused by a single phage infection on bacterial colonies on double-layered agar plates (Fruciano, 2007). He also proposed the name *bacteriophages* which is derived from 'bacteria' and the Greek word 'phagein' which means 'to eat'. In Belgium in 1921, Bruynghe and Maisin reportedly published the first paper on the clinical use of phages after treating cutaneous furuncles and carbuncles in some patients by injection of staphylococcal-specific phages near the base of the cutaneous boils (Wittebole et al, 2014). These patients were reported to have noticable clinical improvement with a reduction in swelling, fever

and pain within 48 hr (Wittebole et al, 2014). Bacteriophages (phages) are a broad class of viruses that infect bacterial cells and can be defined as obligatory intracellular bacterial parasites which lack an independent metabolism. Recent studies of phages have revealed viruses as extremely diversified and ubiquitously present in the biosphere (Curtis, 2005). Accordingly, the sizes of the genome for these phages vary enormously, from a few thousand base pairs up to 234,900 bp (phage vB_AbaM_ME3) which is the largest *Acinetobacter baumanni* bacteriophage sequenced to date (Buttimer et al, 2016). Phages are a relatively untapped reservoir representing the greatest genetic diversity in the biosphere. They contribute to regulation of bacterial population growth and are involved in microbial ecology which drives many global geochemical cycles on earth (Suttle, 2005). Between 20-40% of the bacteria produced every day get killed by phages (Suttle, 2005). Phages just like other viruses consist of nucleic acids surrounded by a protein or lipoprotein coat. The nucleic acid contains ether RNA or DNA but not both; however, the common type in most phages is DNA and it can be double-stranded (ds) or single-stranded (ss). Phages are powerful agents for controlling the composition of bacterial communities. However, not all types of phages can inhibit bacterial growth and some of them may have the side effect of facilitating genetic transfer within the complex microbiomes. Gene transfer between bacteria is a process known as transduction and some of these genes may be toxic and can contribute to bacterial virulence resulting in human diseases (Novik & Savich, 2015). Bacteriophages can be differentially expressed based on environmental factors which can contribute to the survival or clearance of specific bacterial groups from a community (Fister et al, 2016). Phage phiCTX which is a temperate *Pseudomonas aeruginosa* phage has been shown to carry a cytotoxin gene that is expressed in prophage state (Krylov et al, 2013). Some phages can remain in a dormant state allowing the host bacteria to replicate their genomes in a process called the lysogenic cycle. Phages are referred to as prophages, in this state. Moreover, both temperate and virulent phages are involved in the evolution of bacteria through different kinds of transduction (general and specialized) and horizontal gene transfer (HGT), (Krylov et al, 2013). Viruses occupy a unique position in biology, representing an absolute majority of all organisms in the biosphere. With multiple different strains of phages having the ability to infect an individual bacterial species, they are believed to be globally more numerous than bacteria (Essoh et al, 2015). Recently, there has been an increased interest in the use of bacteriophages as antimicrobial agents since the specter of antibiotic resistance has become a larger problem in clinical treatment of patients (La Scola, 2003). Although antibiotics have been successful for treatment of many bacterial infections, the emergence of multi-drug resistant (MDR) bacteria and the failure of drug discovery programs over the last few decades to provide new broad-spectrum antibiotics has highlighted the need to look for alternative treatment methodologies. Many pharmaceutical companies have closed or severely reduced research into novel antimicrobial drugs due to the huge cost of research and development (Thiel, 2004).

MATERIALS AND METHODS

Collecting Samples

Samples were collected from soil surrounding Alexandria Creek, which is located in Alexandria, Calhoun County, Alabama (Latitude: 33.770473° N, Longitude: -85.882815° W, Elevation 630 ft). Ten soil samples were randomly collected in 15 mL sterile conical tubes from five different sites at the location. Field measurements including pH, temperature, depth of sample, as well as other sample descriptions were recorded. Equipment was sterilized before and after collecting samples to avoid any contamination. Samples were transported to the laboratory within an hour of collection on ice.

Bacterial Strains and Culture Conditions

This study was included an ATCC 27853 strain of *P. aeruginos*a. The bacteria were cultured on Luria-Bertani (LB) medium containing 1% tryptone, 0.5 % yeast extract and 0.5 % NaCl (pH 7.2). The bacteria were streaked and incubated at 37°C for 18 hours. All phage exposure/selection was performed using bacteria grown under these conditions.

Phage Isolation and Characterization

Using enrichment culture technique, a 1 mL aliquot of each sample was transferred to a 250 mL baffled Erlenmeyer flask. Using sterile pipettes, 40 mL of autoclaved distilled water, 5 mL of sterile 10X 7H9/glycerol broth, 5 mL AD supplement, 0.5 mL of 100 mM $CaCl_2$ and 5 mL of an 18 hours culture of *P. aeruginosa* were added to the same flask. Flasks then were incubated at 37°C in a shaking incubator at 220 rpm for 24 hours. Next day, 50 mL of each sample was centrifuged at 3,000rpm (2,000 xg) for 10 minutes to pellet. Supernatant was filter-sterilized with 0.22 µm filter and transferred into 50 mL conical tubes and stored at 4°C. Samples were diluted (10^0-10^4). Filtered sterile phage buffer was used as negative control for all samples. Plaque screening was performed using 50 µm of each sample (including controls) added to 5 mL of *P. aeruginosa* into 12 mL culture tubes. Using sterile 5 mL pipettes, a 4.5 mL top agar TA was transferred to the tubes. Immediately mixtures were transferred to LB agar plates and incubated at 37°C for 24 hours.

Electron Microscopy

A high-titre (10^9 p.f.u. ml-^{1}) lysate was sedimented for 60 min at 10,000 x g at 4°C in a SORVALL RC 5B high-speed centrifuge using a SS-34 fixed-angle rotor and was washed twice under the same conditions in phage buffer. Phages were stored at 4°C for 6 hours before staining to allow the pellets to completely dissolve. A 10uL of phage preparation was put onto the grid and kept for two minutes to allowed phages to be adsorbed and examined in a Thermo Fisher TECNAI T12 EM300 electron microscope at the UAB High Resolution Imaging Facility (HRIF).

Sequencing Genomic Characterization

A promega DNA Clean Up Kit was used to isolate and purify phages' genomic DNA. Randomly, 5µL of the DNA was sent for sequence and subsequent bioinformatics analysis. DNA sequencing was performed at the Hudsonalpha Genome Sequencing Center (HGSC) using the MiSeq sequencing system (Illumina, Inc.).

Annotation

The basic features of the LY218 genomic sequence were analyzed using DNAMaster 5.23.2, which was used to align the whole genome of LY218 and compare it with other genomes in the database and GeneMark for positional annotations. Putative ORFs were predicted using ORF Finder with a threshold of 75 amino acids as a minimum length of the protein. Among the 88 protein coding genes, presumptive function of 86 proteins were called based on homology determined by Predict Protein. The 3% difference between Phi176 and LY218 sequences is centered on two proteins of indeterminant function. Sequencing of the LY218 genome revealed a dsDNA with 54.87% G+C content and 356 open reading frames (ORFs) which were predicted to be coding sequences. Gene prediction was also performed using DNAMaster. Similarities with a minimum confidence level of 97%, was used with the BLAST algorithm available in NCBI.

RESULTS AND DISCUSSION

Isolation of Phages

Ten samples of soil were screened for the presence of LY218 phage. Two were positive for LY218 phage. The phage was virulent and formed clear plaques of 3-4 mm diameter on lawns of *P. aeruginosa* with LB soft agar (Fig 1). *P. aeruginosa* strain ATCC 27853 was sensitive to LY218 in both the drop titration test and with soft agar plating assay. Plaques formed within 18 hr.

Electron Microscopy

Under transmission electron microscopy, LY218 showed an isometric head of 84-85 nm between opposite apices, and a neck with a collar of 6x8 nm and a tail of 10x12 nm in extended state (Fig 2).

Genome Characterization and Sequence Analysis.

This isolate is 73083 bp and it is 97% identical to the *Pseudomonas* phage Phi176, a phage isolated and sequenced in Bath, England. A total of 88 presumptive genes have been identified. Presumptive function of 71 proteins were called based on homology determined by PredictProtein. The 3% difference between these two phage sequences is centered on two proteins of indeterminant function. Sequencing of the LY218 genome revealed a dsDNA with 54.87% G+C content and 356 open reading frames (ORFs) were predicted to be coding sequences.

This is a newly discovered double-stranded DNA (dsDNA) phage of the family *Podoviridae* of short tailed phages and the order *Caudovirales*. Phages of this genus typically have genome size of 18,000 bp to 500,000 bp. The order *Caudovirales* constitutes ~ 96% of all known phages (Fokine & Rossmann, 2014). About 94.2% of the known phages that have been used in phage therapy to treat *Pseudomonas* species have been found to belong to the *Caudovirales* order, which includes three families of dsDNA phages (Diana P. Pires, Sillankorva, & Azeredo, 2015). These three phage families differ in the physical characteristics of the phage tail: *Myoviridae*, are known to exhibit a long and contractile tail, *Podoviridae*, has a short and nonconcontractile tail, and *Siphoviridae*, a long and nonconcontractile tail (Diana P. Pires, Sillankorva, & Azeredo, 2015).

The full nucleotide sequence of the genome of LY218 has been determined, and this has been deposited (The NCBI accession number is MN906996). A BLAST analysis revealed that this isolated phage (LY218) genome had a query cover of 100%, and a highest identity of 97% with *Pseudomonas* phage Phi176. Phi176 was submitted to the International Committee on Taxonomy

of Viruses (ICTV) in May 2015. Also, it was submitted to the GenBank database with accession number KM411960, and a total linear genome length of 73,048 bp. However, it has not been annotated yet. Phi176 was first discovered in Bath, England (NCBI, n.d.). To reveal the relationship between LY218 and other members of *Podoviridae*, a phylogenetic tree was constructed using VICTOR, and LY218 was closely related to *Pseudomonas* phages Phi176, Pa2 and PhiCB2047-B (Fig 3).

A total of 88 presumptive genes have been identified. Presumptive function of 71 proteins were called based on homology determined by PredictProtein. The 3% difference between these two phage sequences is centered on two proteins of indeterminant function. In fact, there were no homologous protein structures in the NCBI protein database. Sequencing of the LY218 genome revealed a dsDNA with 54.87% G+C content and 356 open reading frames (ORFs) that were predicted to be coding sequences. The high homology between LY218 and Phi176, could raise an important question; Could it have been transported by individuals? Sea, air and land transport networks increasingly continue to expand in reach. Also, volume of passengers, speed of travel and goods carried significantly increased in the last few years. This could make pathogens and their vectors disseminate more broadly. Furthermore, immigration of birds and stratospheric movements of winds, dust and clouds overseas would be another possible way for viruses to be transmitted through the atmosphere. For instance, during the Summer, African dust storms transport across the Atlantic to the northern Caribbean and North America (Griffin, 2007).

Phages ϕIBB-SL58B and ϕIBB-PF7A, which belong to the *Podoviridae* family, have a short and non-contractile tail. Both phages have been tested on biofilms of *Pseudomonas fluorescens* and *Staphylococcus lentus* and showed efficient lysis of biofilms (Sillankorva, Neubauer, & Azeredo, 2010). This suggests that LY218, could potentially be effective on biofilms of *Pseudomonas aeruginosa* and potentially other bacterial species. Furthermore, Phi176, LUZ7, LIT1, Pa2 and KPP21 belong to the N4-like phages (Shigehisa, et al., 2016). This indicates that LY218 belongs to the N4-like phage group and it is sharing a similar gene order and possessing all 18-core gene that were found among all N4-like members (Buttimer, et al., 2018). This group of phages is highly conserved worldwide because N4-like viruses are assumed to have high adaptation level to *P. aeruginosa* as a new host bacterium (Shigehisa, et al., 2016).
Three of the currently available fifty-nine complete genome sequences of *P. aeruginosa* are closely related to ATCC 27853 strain (Huiluo Cao, Lai, Bougouffa, Xu, & Yan corresponding, 2017). Those strains can cause many human infectious diseases including burn infections, sepsis, cystic fibrosis (Forti, et al., 2018) keratitis, urinary tract infections (UTIs), as well as acute and chronic infections of human airways (Huiluo Cao, Lai, Bougouffa, Xu, & Yancorresponding, 2017). LY218 could be potentially used to design a phage cocktail that reduces *P. aeruginosa* biofilms and acute infections in humans.

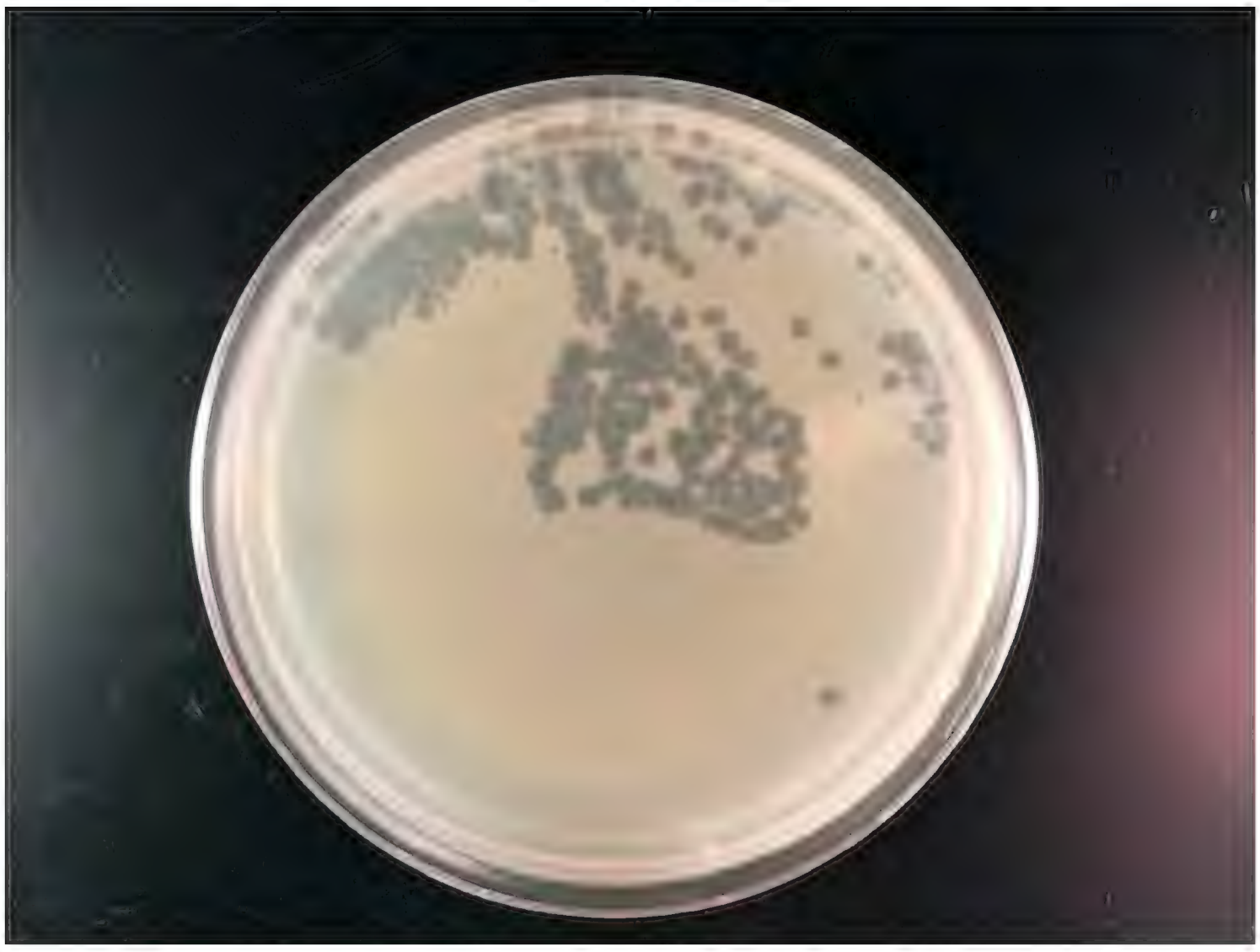

Figure 1: Bacteriophage plaques of LY218 on a Luria-Bertani (LB) agar plate.

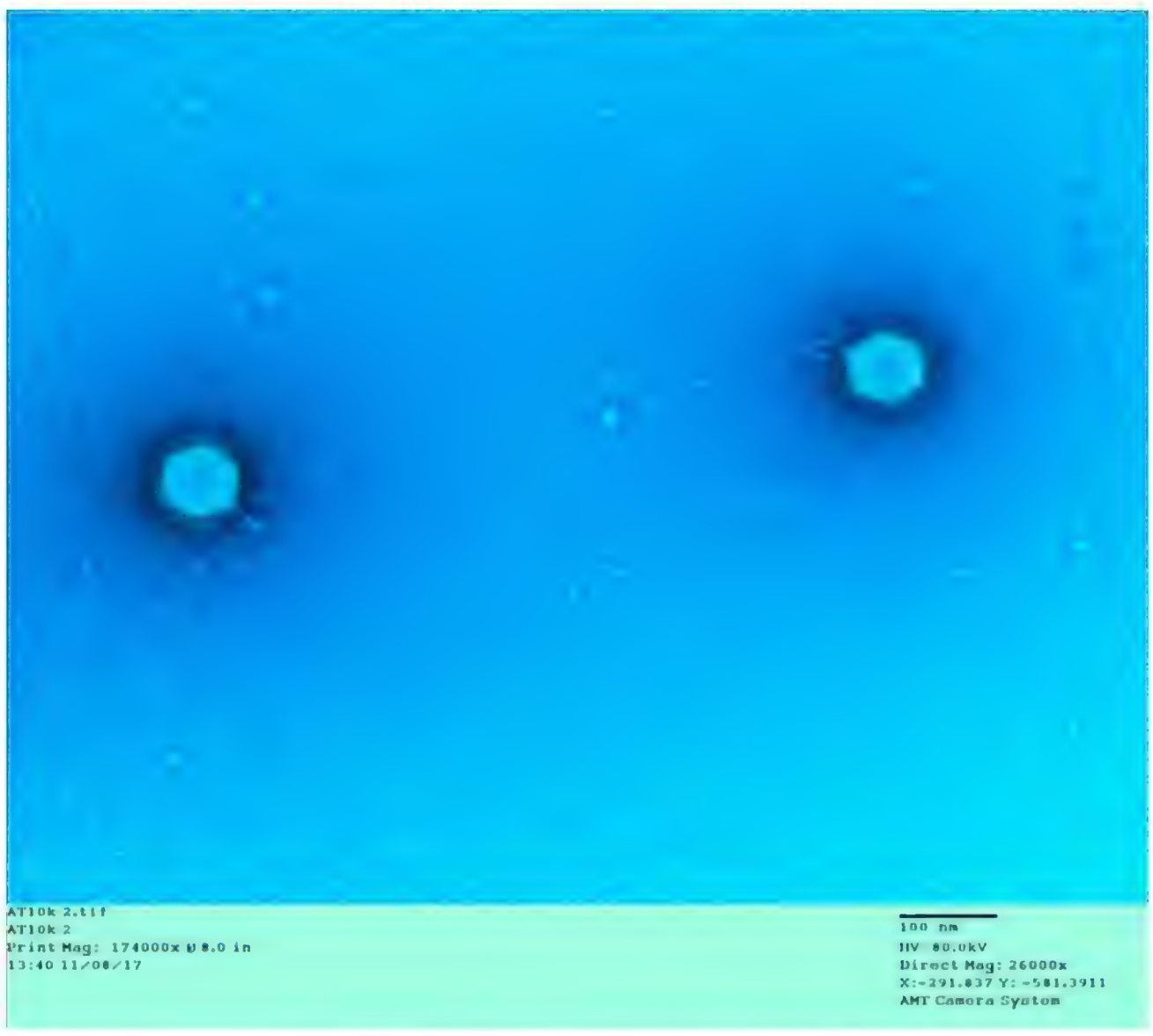

Figure 2: Electron micrograph of LY218, a bacteriophage of Pseudomonas aeruginosa ATCC 27853.

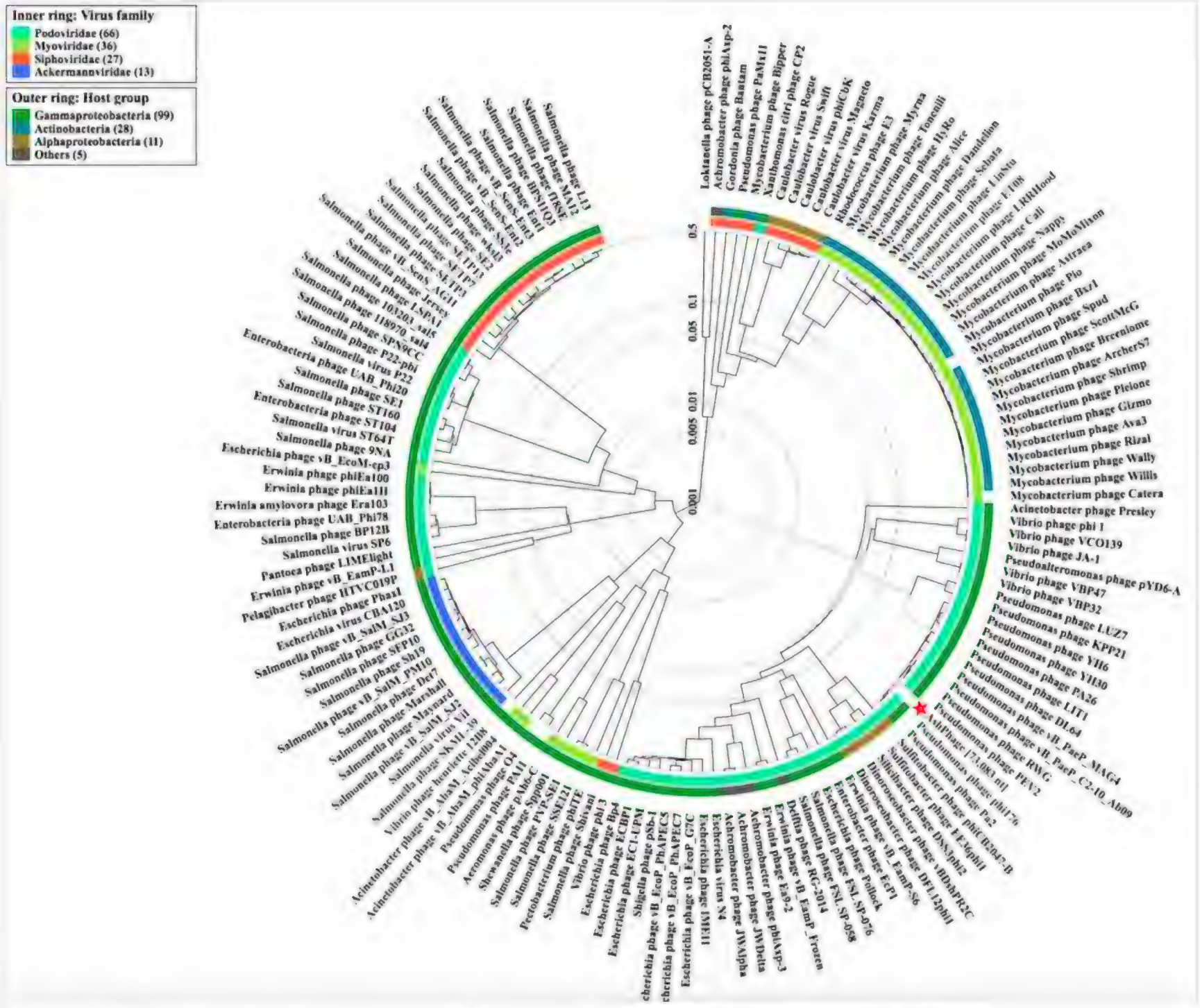

Figure 3: Dendrogram showing the phylogenetic affiliation of LY218 a bacteriophage of *Pseudomonas aeruginosa* ATCC 27853, Jan P. Meier-kolthoff and Markus Goker (2017). Red star on the dendrogram shows LY218.

ACKNOWLEDGMENTS

This paper and the research would not be possible without the exceptional support of Dr. Blair and Dr. Murdock. Also, I am most thankful for the School of Science and Department of Biology here at Jacksonville State University for providing financial support and lab space.

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TWO VARIANTS OF SLC6A1 ON AMINO ACID 451 (D451E AND D451G) ASSOCIATED WITH DEVELOPMENTAL DELAY AND EPILEPSY

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ABSTRACT

We present two case studies on the same allele and amino acid. The result of both variants is early onset of developmental delay and seizures. SLC6A1 is associated with an autosomal dominant early onset seizure and epileptic encephalopathy and intellectual disability. Genomic studies reported in ClinVar revealed two variants D451E and D451G. The amino acid substitution suggests that glycine would be predicted to be slightly more detrimental simply based on the physical differences between aspartic acid and glycine. Glutamic acid is similar to aspartic acid in structure and both are negatively charged amino acids. Structural and evolutionary assessments establish these variants represent a loss of function to the protein. Compiled metrics through custom tools on sequence, structure, and protein dynamics combined with PolyPhen2, Provean, SIFT, and Align-GVGD reveal these variants to rank in the top functional outcome changes relative to gnomAD, TOPMed, and ClinVar variants known to date. It is not known if these patients are resistant to multiple epileptic drugs; however, it has been noted that other variants in the same vicinity as these two respond better to valproic acid in controlling the seizures. This is consistent with additional groups studying SLC6A1 variants within patients.

INTRODUCTION

SLC6A1 encodes for a GABA transporter responsible for the reuptake of GABA from the interstitial space around the synapse after neural stimulation. A rare genetic disorder SLC6A1 epileptic encephalopathy is caused by a dominant, de novo mutation in SLC6A1, resulting in the loss of the transporter protein function. This results in development of seizures in early childhood with mild to moderate intellectual disability (ID) and behavioral disorders found in severe autism (Mattison, et al, 2018; Johannesen, et al, 2018; Yuan et al, 2017). Mutations in SLC6A1 have been found in association with myoclonic-atonic epilepsy, and other symptoms including language impairment, dystonia, and schizophrenia. However, the significance of many variants is currently unknown (Carvill, et al, 2015; Rees et al, 2020; Zech et al, 2017). For example, recent research has shown that although G443D is a far outlier for functional impact and structural fold

contribution, it has a critical loss-of-function role (Devries, et al, 2020). Their novel strategy is recommended for future SLC6A1 variant assessments and applied in this study.

Compiled metrics and statistics comparing these variants to all the known variants listed in ClinVar (Landrum et al., 2016), TOPMed, and GnomAD (Lek et al., 2016) as well as evolutionary comparison to 225 species has established a method for determining the impact of variants as it relates to other known samples. A 21-codon impact score statistical analysis was developed for detection and prediction of individual motif involvement in the development of disease. We utilize the YASARA set of tools (Krieger et al., 2009) to model changes in the protein.

Data was compiled for variants of known pathogenicity and variants of unknown significance (VUS) from databases of patients with a variant in this gene. The VUS D451E and D451G (Table 1) were compared to all known variants by analyzing and interpreting this data. Molecular dynamics simulations (mds) provided additional information about the variant impact on protein movement in a computationally derived cellular environment by analyzing movement trajectories.

CASE PRESENTATION

The D451G variant of SLC6A1 was submitted by HudsonAlpha Institute for Biotechnology (Huntsville, AL) and is listed as a variant of uncertain significance with myoclonic-atonic epilepsy as a de novo mutation with resulting autism spectrum disorder, moderate intellectual disability, seizures, and speech delay in a male in his early 20s. [NM_003042.4(SLC6A1):c.1352A>G (p.Asp451Gly)] (ClinVar Miner). Funding for this sequencing was obtained from National Human Genome Research Institute (NHGRI), UM1HG007301.

Variant D451E (SCV000742016 was submitted by Ambry genetics (Aliso Viejo, CA)) is listed as a variant of uncertain significance. It is also listed as a possible hereditary disease, a germline disease resulting in seizures, movement disorders, dysmorphic features, FTT/undergrowth, and hypotonia. Additionally, childhood onset of cardiovascular, dental, dermatologic, musculoskeletal, neurologic, and audiologic effects. [NM_003042.4(SLC6A1):c.1353C>G (p.Asp451Glu)] (ClinVar Miner).

There is limited availability to the case histories of these two variants. Generally, pathogenic effects from SLC6A1 are noticeable by two years of age and many of the variants are resistant to multiple types of the most current seizure medications (Devries, et al, 2020). It has been noted in close variants (G443D) that one of the oldest antiseizure drugs on the market, valproic acid, is more effective with variants of this gene (Devries, et al, 2020). Valproic acid does require significant monitoring to ensure side effects are not a confounding factor.

MATERIALS AND METHODS

Variants were assessed through our previously published sequence-to-structure-to-function workflow (Prokop et al. 2017), comparing the patient variant to all gnomAD (Lek et al., 2016), TOPMed, and ClinVar (Landrum et al., 2016) missense variants for SLC6A1. All variants were assessed with PolyPhen2 (Adzhubei et al. 2010), Provean (Choi and Chan 2015), SIFT (Ng and Henikof 2003), and Align-GVGD (Tavtigian et al. 2006). A total of 20 nanoseconds of molecular dynamics simulations were run on a lipid membrane embedded SLC6A1 protein model and both variants were modeled from this template using the AMBER03 force field (Duan et al. 2003).

RESULTS

The SLC6A1 protein model with 599 amino acids was generated and embedded within a lipid membrane (Fig. 1 A, B). The model is shown in grayscale with the 451-residue highlighted in red, all other molecular markers and membrane have been hidden to give a clear 3D image of the model (Fig. 2). For each amino acid position, the conservation score was examined for linear motif conservation. This was done using a 21-codon sliding window additive scoring system where the scores of 10 amino acids before and after each position were used to find the most conserved linear motifs within this protein. Position 451 was among the highest conservation scores (Fig. 3). Variant impact shown in the scatterplot for all gnomAD/TOPMed, and ClinVar variants reveals the D451G and D451E mutations both fall near several other ClinVar variants with high variant impact scores (Fig. 4). The impact score, shown in box plot format, demonstrates that the D451G has slightly higher impact than the D451E, yet both are near the top of the likely pathogenic to pathogenic groups (Fig. 5). The mds revealed a root mean squared fluctuation (RMSF) of variant groups where both the variants at amino acid 451 cluster with the pathogenic and likely pathogenic groups (Fig. 6). The conservation score for 225 species of animals for SLC6A1 was calculated and conservation scores for the 21-codon window (10 below and 10 above) for position 451 showed high conservation in the region surrounding 451 (position 11). This suggests that it is highly likely to induce changes in protein function if an amino acid is substituted into the site (Fig. 7). The mds data supports D451 to be critical in folding of the protein, with movement below average. The global deviation chart shows movement of D451G is above the wildtype (Fig. 8) This data supports D451G to be a loss-of-function site for SLC6A1. This is consistent with reported neurological conditions of the patients and the models. SLC6A1 has been associated with myoclonic atonic epilepsy with some variability in epilepsy types, while most all patients have intellectual disability similar to this patient (Johannesen et al. 2018).

DISCUSSION

In conclusion, we identified variants in SLC6A1, namely D451G and D451E, that were associated with seizures and developmental delay. Based on comparison to all known variants in SLC6A1, D451 was found to be an outlier for functional impact and structural fold contribution indicating a potential loss-of-function role in SLC6A1. The sequence-to-structure-to-function strategy was useful for VUS assessment and is recommended for future screening projects. Our statistical analysis of the data suggests that both 451 variants are most likely pathogenic in nature. The VUS have different physiochemical properties and the structure of D451G is less similar to the original amino acid than D451E. The case study indicates D451G was associated with patient reports of *late* development neurological disorders and seizures. In contrast, D451E is a negative charge to negative charge mutation, and is associated with *early* onset of developmental delay and seizures. Overall, analysis suggests mutations at position 451 play a role in the development of the SLC6A1 epileptic encephalopathy with myoclonic-atonic seizures disorder.

The fact there is such a difference in the amino acids and variations across the length of the protein gives reason to conjecture that mutation at this site most likely hinders the function in some way. Additionally, it is conjectured that the transmembrane domains are aligned very specifically and any change in alignment of these domains will result in lower transport of the normal molecules. However, more research must be conducted to confirm these hypotheses. Now that the simulation has been developed it may be possible to model potential drug-ligand interactions to determine which drugs may be more effective with certain groups of variants. More work needs to be

completed before stringent protocols for determining the VUS status of this gene can be developed, but this study represents a step toward establishing that protocol.

ADDITIONAL INFORMATION

No IRB statement or ethics are of concern since all information was obtained from publicly available databases and the information was already FERPA certified.

No funding was provided for this analysis.

AUTHOR CONTRIBUTIONS

Benjie Blair and Cynthia Stenger were prime lead geneticists on the project. Jared Painter was responsible for molecular dynamics simulations. Jeremy W. Prokop was a mentor on all bioinformatic variant interpretation. Sara Woodley was a student investigator. Richard Watkins was involved in informatics and figure creation. Jenna Ridlen is a clinical DO who contributed her medical expertise. All authors contributed to the writing of the manuscript.

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TABLES AND FIGURES REFERENCED IN RESULTS

TABLE 1. Genomic Findings

Gene	Variant	Zygosity	Variant Classification	Inheritance
SLC6A1	D451G	Heterozygous	VUS	De Novo
SLC6A1	D451E	Heterozygous	VUS	De Novo

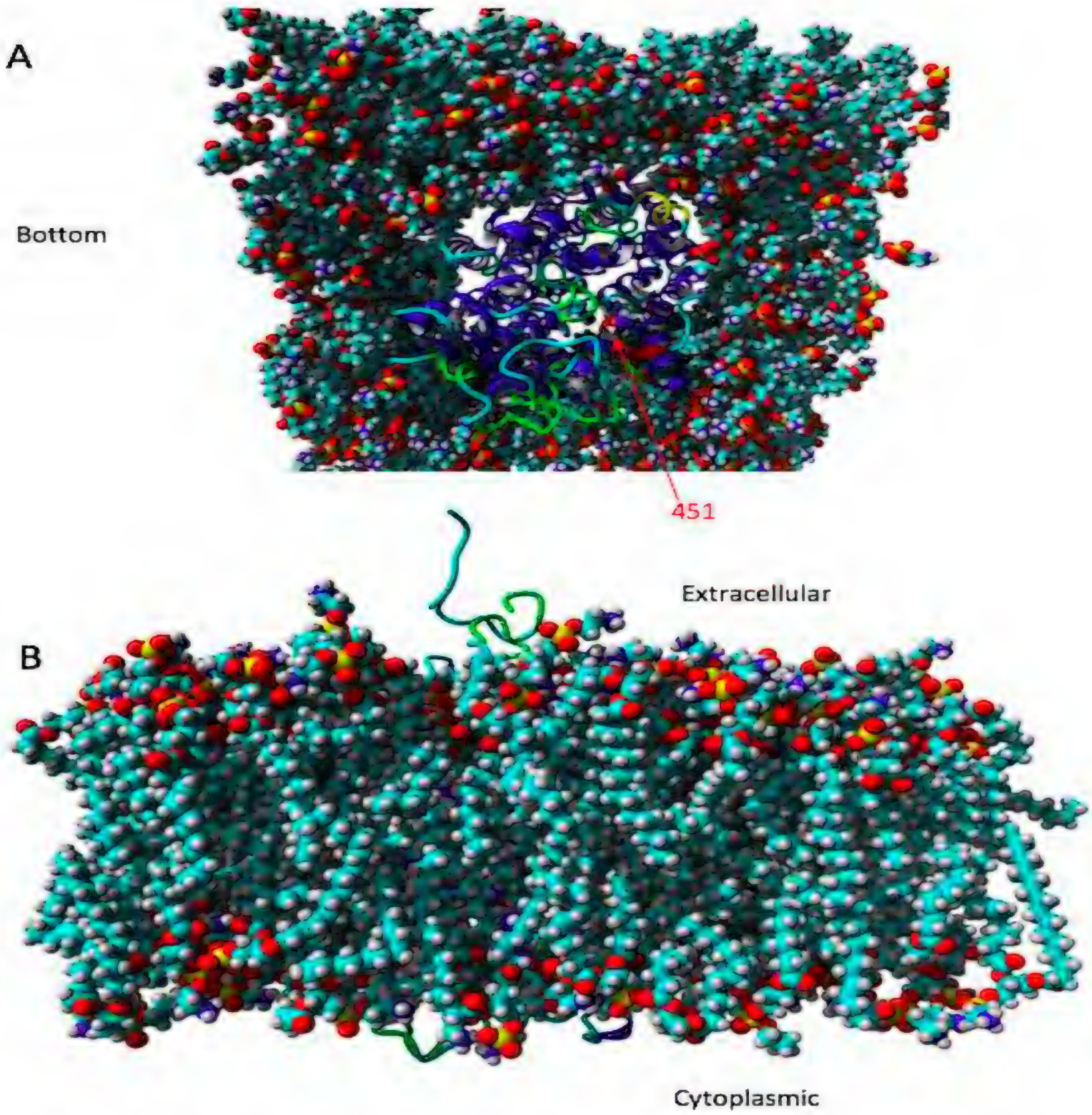

Figure 1. SLC6A1 variant analysis. A-B) Structural model of SLC6A1 (multicolor) in a lipid membrane **A.** looking up from the cytoplasmic side. **B.** Side view (cross section) of the protein modeled in a typical phospholipid membrane.

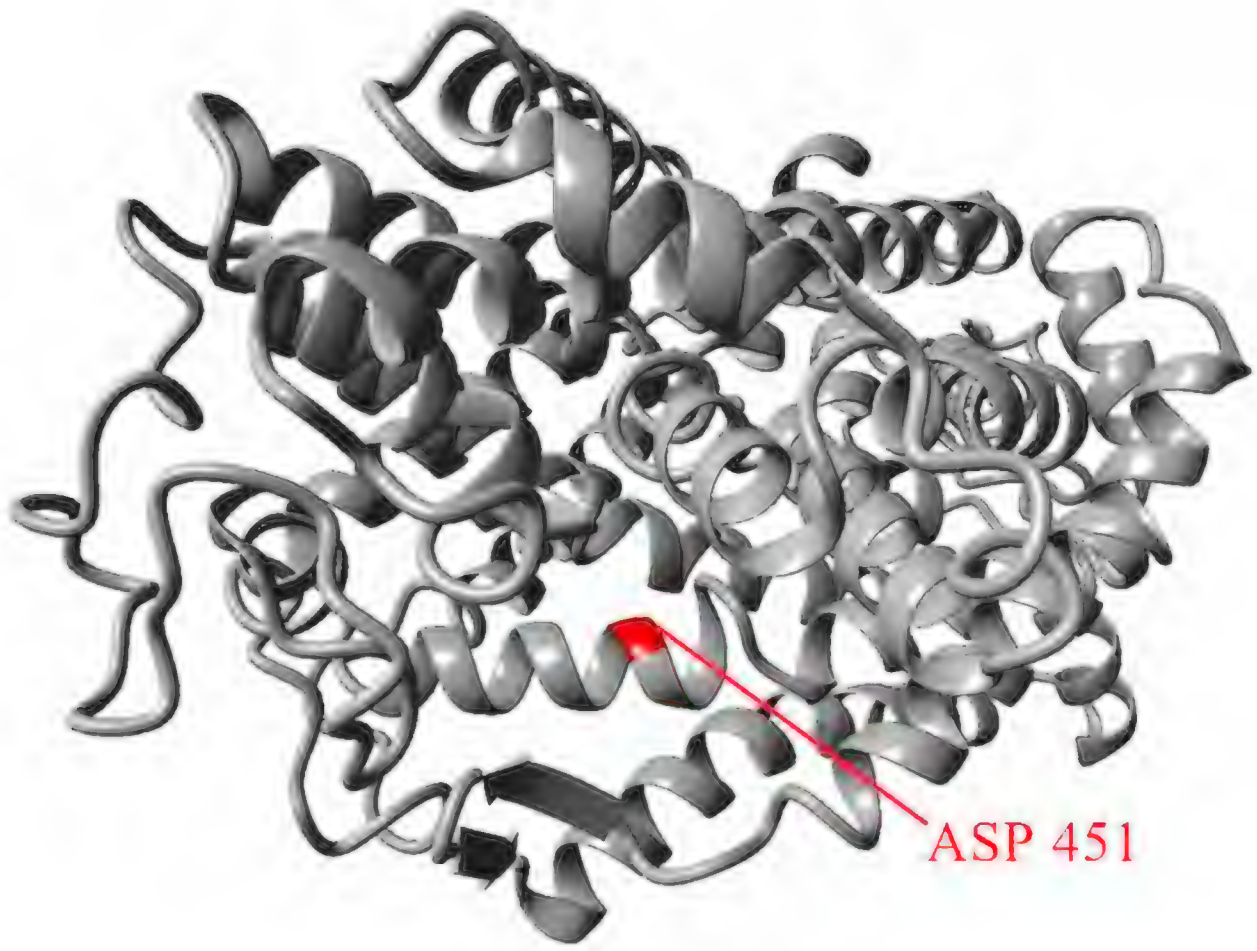

Figure 2. The protein is shown up close with the 451 position marked. The model was performed in a membrane matrix but that has been hidden for ease of viewing. This demonstrates that the variant location is close to the end of an alpha helix and is packed into the middle of the protein.

Figure 3. ORF (open reading frames). Deep evolutionary analysis using 225 species open reading frame sequences for SLC6A1. The plot shows a sliding window calculation for each site (plus ten up and downstream), finding the most selected and conserved linear motifs within the gene. Amino acid 451 is showed in red.

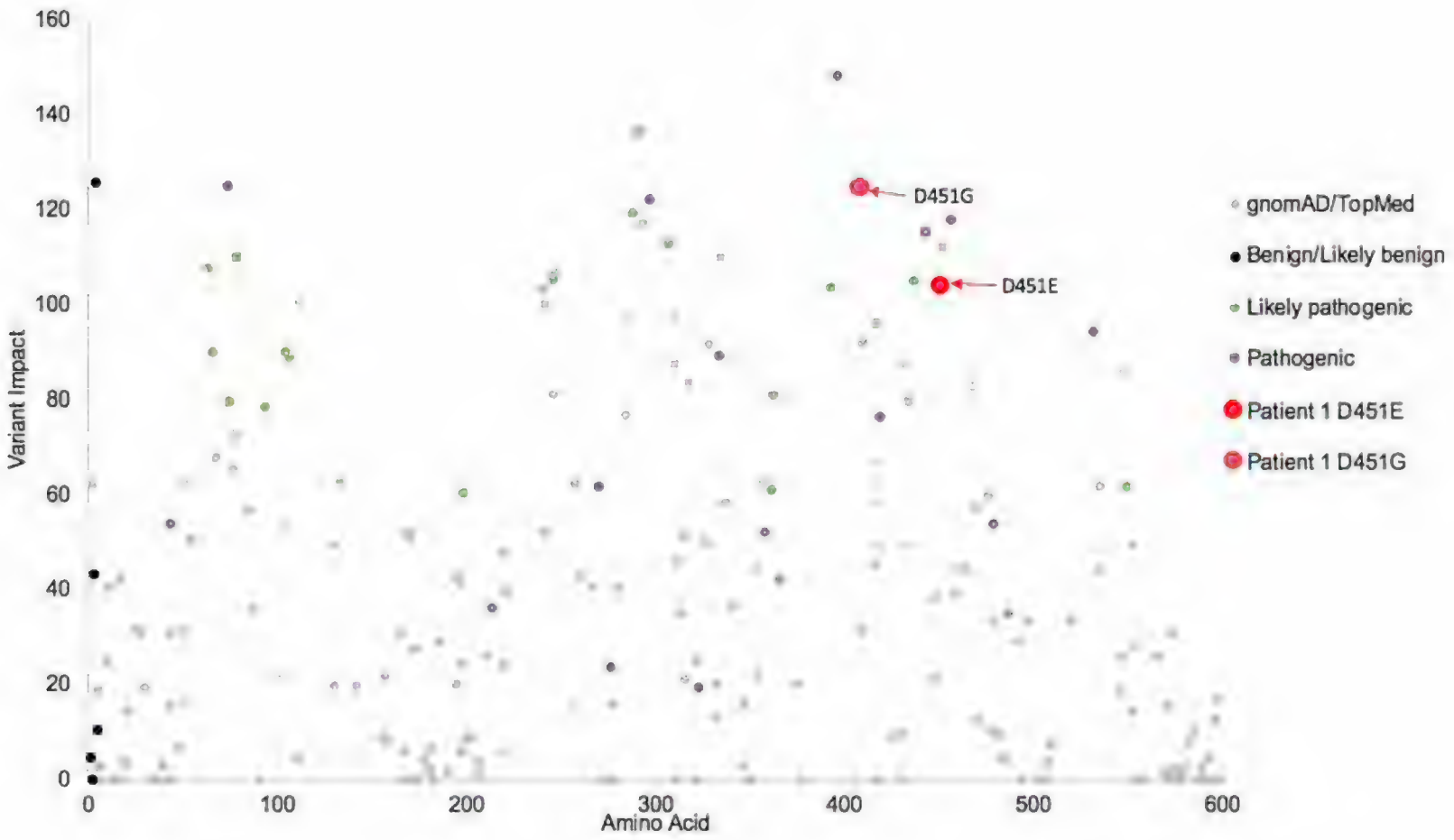

Figure 4. Scatterplot with variant impact scoring for all gnomAD/TOPMed (gray), ClinVar (benign-black), likely pathogenic-(light green), pathogenic-magenta), and patient 1 (cherry red), patient 2 (Maroon) (dots for patients were enlarged slightly) variants for SLC6A1.

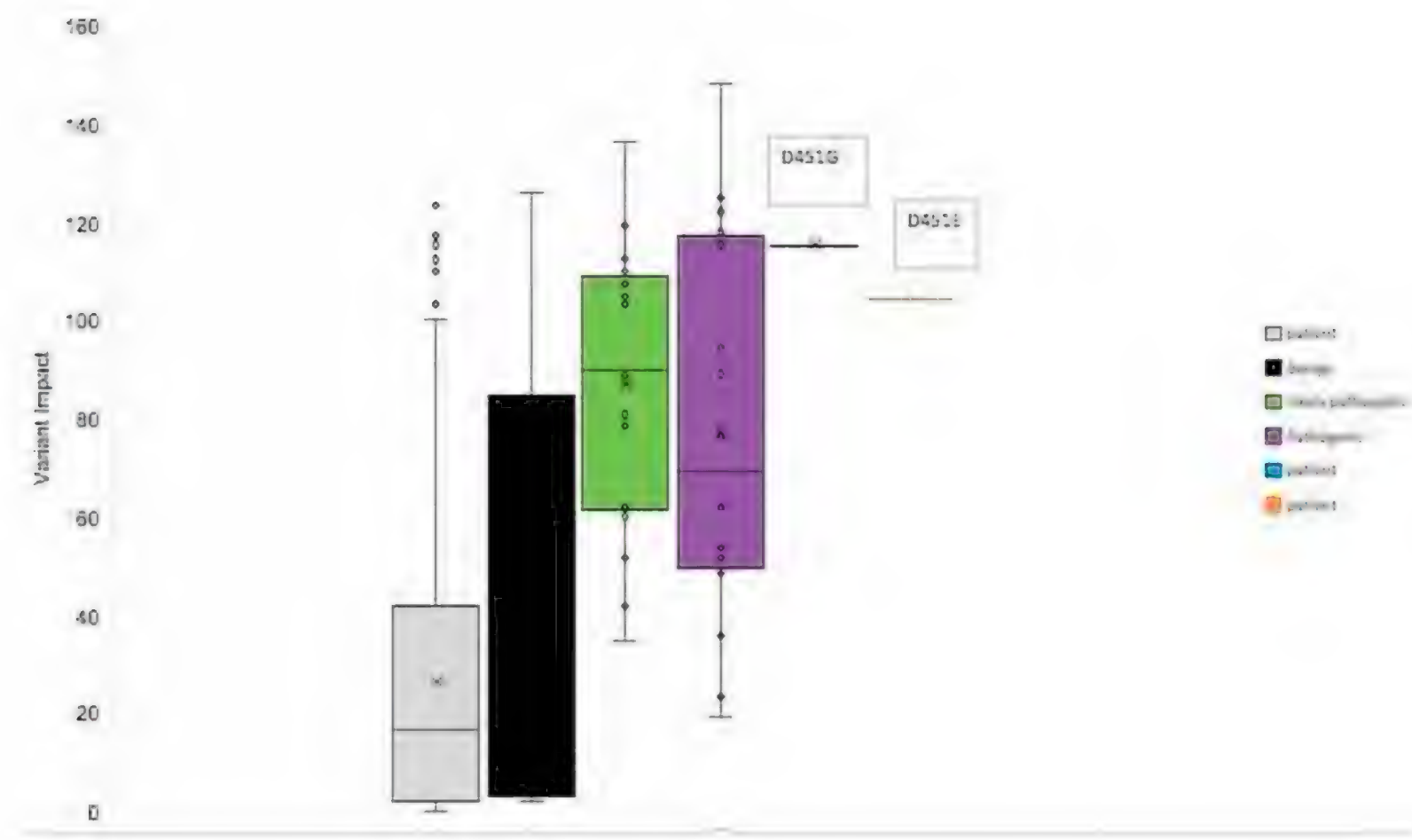

Figure 5. The impact difference between the two variants can be easily seen in a box and whisker plot where both variants are near the top of the pathogenic grouping. Box and whisker plot for each group plotted series 1 are unclassified (lite gray), Benign/likely benign in black, likely pathogenic green, pathogenic purple. Variant D451G and variant D451E.

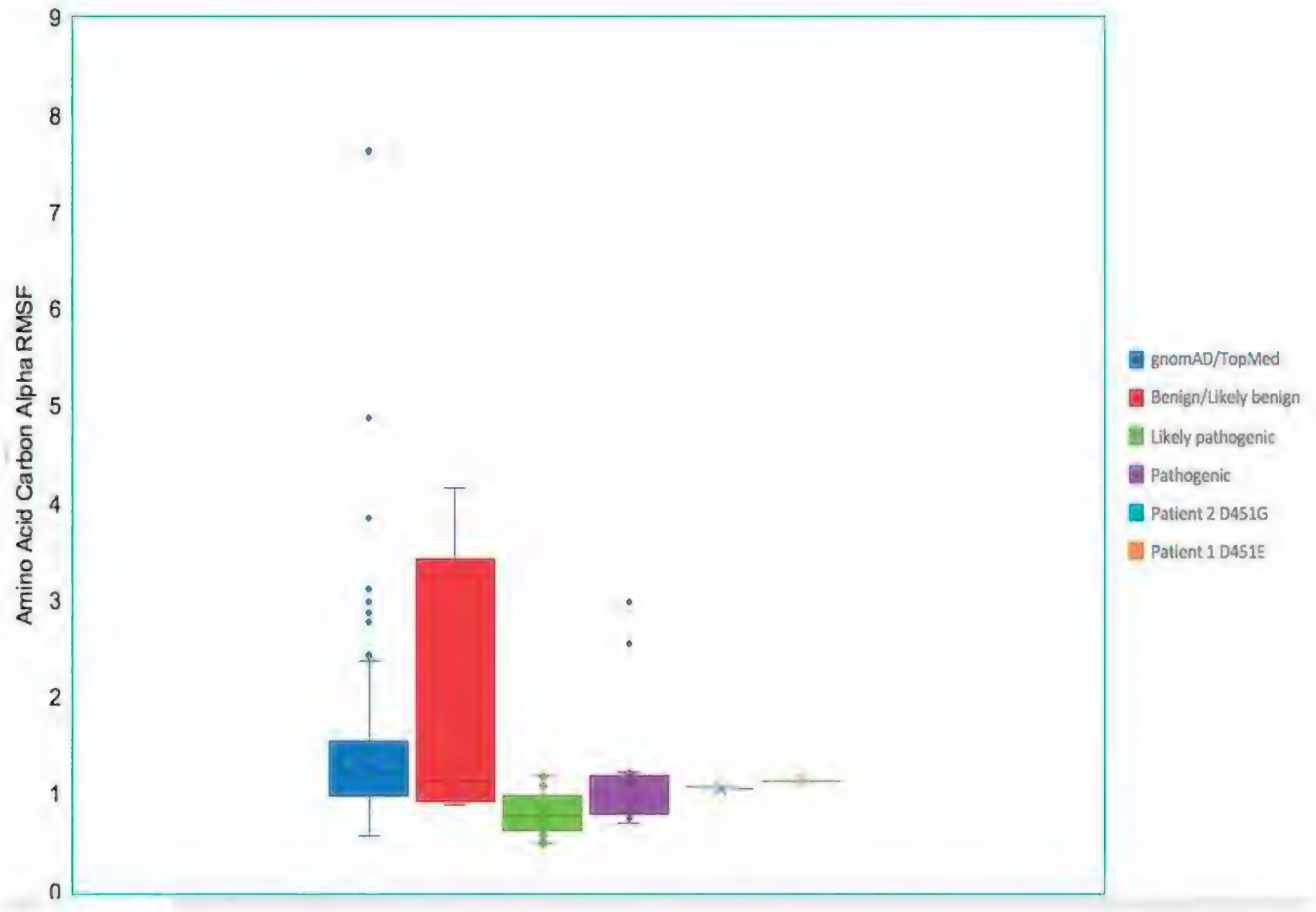

Figure 6. Root mean squared fluctuation (RMSF) of variant groups. With gnomAD/TOPMed (dark blue), Benign/likely benign (dark red), Likely pathogenic (green), pathogenic (purple), Patient 2 (light blue), patient 1 (orange).

Figure 7. Zoomed in view of conservation for amino acid 451 (red) linear motif. The numbers above represent the percent of sequences with synonymous / nonsynonymous variants throughout evolution.

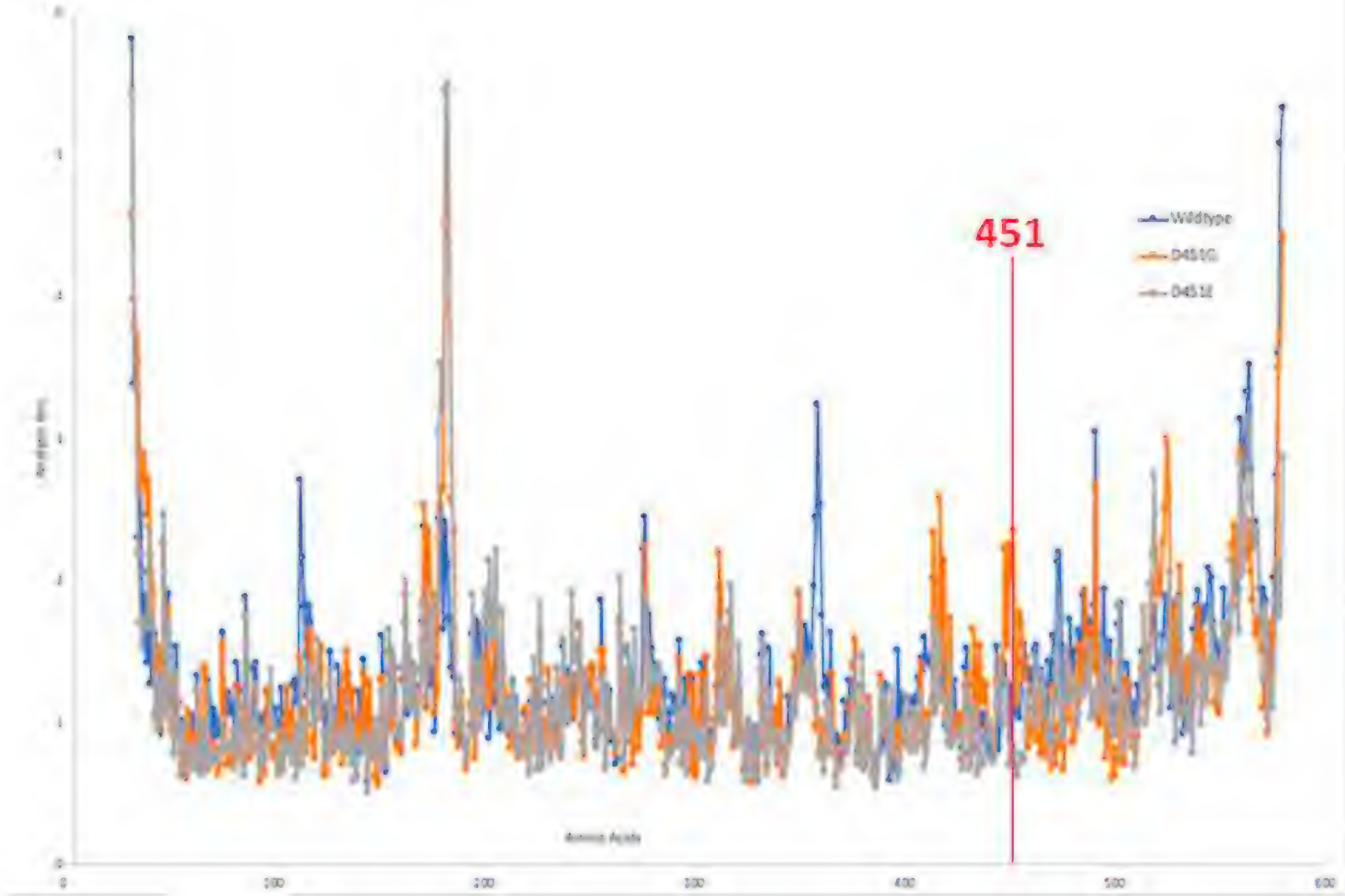

Figure 8. Global deviation of the wild type plus the variants shows D-G more affected than D-E as predicted by the biophysical properties of the amino acids.

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AN EXAMINATION OF THE SUNSPOT AREAL DATASET, 1875–2017: PAPER I, AN OVERVIEW

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ABSTRACT

Examined are annual values of sunspot number (SSN), corrected sunspot area (SSA), number of active region entries (NARE), largest-observed area active region (LAAR), mean area per entry (MAE), highest latitude spot (HLS), and inferred correlations between selected parameters based on the observed data for the years 1875–2017. A number of ±1 standard error of measurement prediction intervals are made regarding the size of the next sunspot cycle (SC) SC25. In particular, based on the even-odd cycle effect, SC25, the next solar cycle, should have maximum annual SSN = 170.4 ± 13.7, maximum annual SSA = 1,730.3 ± 180.0 millionths of a solar hemisphere, and maximum annual NARE = 3,775 ± 510, assuming that it is not a statistical outlier. Also, based on the observed annual minimum value of HLS for 2017 (= 19°), one predicts minimum annual SSN = 7.0 ± 3.2, minimum annual SSA = 41.5 ± 31.7 millionths of a solar hemisphere, minimum annual NARE = 155 ± 76, maximum annual SSN = 136.2 ± 14.8, maximum annual SSA = 1,461.5 ± 261.2 millionths of a solar hemisphere, and maximum annual NARE = 2,771 ± 330 for SC25. As of March 2019, there have been no occurrences of high-latitude new-cycle spots (≥30°) during the decline of ongoing SC24. Monthly values of SSN, SSA, and NARE are now well within the range of expected values indicative of the approaching SC24/25 cycle minimum, especially values since November 2017. Hence, another prolonged cycle-minimum period, as was experienced for SC23/24, may be underway for SC24/25.

INTRODUCTION

Sunspot number (SSN) has been described as being the "longest available record of solar activity," spanning some four centuries in length (Clette et al. 2007). While true, it should be noted that, prior to the use of telescopes, "spots on the Sun" had previously been described by many ancients going back more than 2,000 years, including Theophrastus, Virgil, Abu Alfadhl Giaafar, Averroës of Cordoba, and others (Shove 1950; Hoyt and Shatten 1997; Vaquero et al. 2002; Vaquero 2007; Vaquero and Vázquez 2009; Zito 2016). Even today, "naked-eye sunspots" can occasionally be glimpsed, especially if they are large (cf. Keller and Friedli 1992), and the brighter disk of the Sun is highly attenuated (i.e., through thick clouds, fog, smoke, or when the Sun is close to the horizon).

More recently, sunspot area (SSA) also has come to be used as a general descriptor of the variation of solar activity. In particular, Richard Carrington introduced the technique of photography for measuring SSA at the Royal Observatory in Greenwich, England, in 1874 (Kiepenheuer 1953). Together, images of the Sun taken with photographic plates from Greenwich, England; Cape Town, South Africa; and Kodaikanal, India, have been combined into what is known today as the *Greenwich Photoheliographic Results*, a dataset spanning May 1874 through December 1976 (cf. Yallop and Hohenkerk 1980; Willis et al. 2013). It should be noted that SSA observations are especially important for describing the cyclic and long-term variation of the Sun's

magnetic fields and solar irradiance (cf. Baranyl et al. 2001; Baumann and Solanki 2005; Wilson and Hathaway 2005, 2006; Pevtsov et al. 2013; Hathaway 2015; Wilson 2015).

In an effort to extend the SSA dataset beyond 1976, David Hathaway, a former National Aeronautics and Space Administration (NASA) solar scientist (now retired) utilized solar observations from the Solar Optical Observing Network (SOON) of the United States Air Force (USAF) and the National Oceanic and Atmospheric Administration (NOAA), reformatting them to conform to that of the Royal Greenwich Observatory (RGO) dataset, to provide the necessary data. Together, the combined datasets form the basis for the sunspot areal dataset that extends from May 1874 through the present (see http://solarcyclescience.com/activeregions.html). (Included at the website are comments describing the format of the data and detailing the changes to the data since 1977. It is important to remember that the RGO dataset is one based on photographically determined results, while the USAF/NOAA SOON dataset is one based on visually determined results.)

This paper (Paper I) is anticipated to be the first of at least three papers that will examine the annual variations and inferred correlations that are apparent in the sunspot areal dataset. Paper I provides a general overview of some of the data and examines the inferred relationships to SSN and other parameters, while Paper II will examine annual hemispheric variations, and Paper III will examine annual variations of the magnetic complexity of sunspots.

METHODS AND MATERIALS

Two primary data sources are employed in this study: (1) annual SSN values, available online at http://sidc.oma.be/silso/datafiles, and (2) annual SSA values, available online at http://solarcyclescience.com/activeregions.html. Other parameters taken from the SSA dataset for (a) the RGO interval 1875–1976 and (b) the USAF/NOAA interval 1977–2017 include (1) the yearly total number of active region entries (NARE), (2) the yearly largest-observed active region area and its magnetic classification (LAAR/MC), (3) the yearly mean area per entry (MAE), and (4) the yearly highest latitude sunspot (HLS). Standard statistical analyses are employed in this study and in the presentation of the results. The magnetic classification (MC) of sunspots will be addressed in Paper III.

RESULTS AND DISCUSSION

Figure 1 displays the annual variation of SSN for the interval 1875–2017 (thin line) and the estimated value for 2018 (dashed line) for sunspot cycles (SCs) SC12–SC24. The thick horizontal line is the overall mean, being 82.2 and having a standard deviation *sd* of 64.2 units of SSN. The year marking the division between the RGO and USAF/NOAA datasets is identified (1977), as are the means and *sd*s for the two independent intervals RGO: 1875–1976 and USAF/NOAA: 1977–present. The *t* statistic for the difference in the means for the two independent samples (Lapin 1978) is computed to be $t = -1.1218$, which by hypothesis testing suggests that the difference in means for the two intervals is not statistically significant.

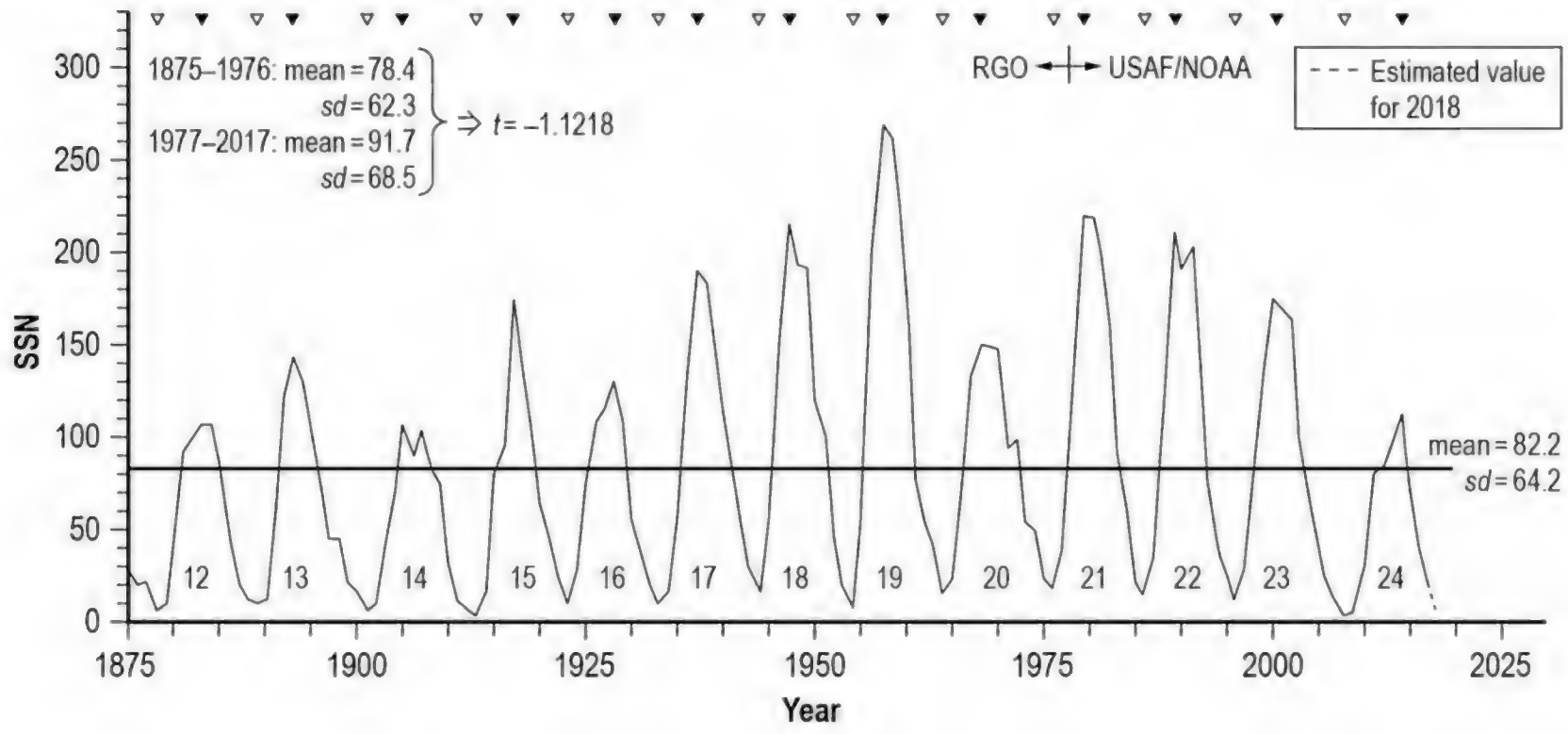


Figure 1. Variation of annual sunspot number (SSN), sunspot cycles (SCs) SC12–SC24. SSN minimum value (min) for each cycle is identified by unfilled triangles, and SSN maximum value (max) for each SC is identified by filled triangles. The interval 1875–1976 represents the Royal Greenwich Observatory (RGO) timeframe, whereas the interval following 1976 represents the United States Air Force/National Oceanic and Atmospheric Administration timeframe. The *t* statistic for independent samples is given.

Notice that each SC has a minimum SSN value (SSN min) and a maximum SSN value (SSN max), denoted by unfilled and filled triangles, respectively. Based on the annual values of SSN, one finds that the rise from SSN min to SSN max has generally been 3–5 years, with only SC24 having a longer rise (6 years). Also, the decline from SSN max to the following SSN min has usually been 7–8 years, with only SC12, SC15, and SC16 having shorter descents (6, 6, and 5 years, respectively). One also observes that the descent is usually 4 years longer than the rise for all SCs except SC12, SC15, and SC16, where these cycles have differences in length as compared to their rise of 1, 2, and 0 years longer, respectively. The duration (or period) of SCs from leading SSN min to following SSN min has always measured 10–12 years. Because SC24 remains ongoing, its descent and SSN min-SSN min duration are yet to be determined, although one strongly suspects that its descent will be ≥6 years, thus yielding SSN min-SSN min duration ≥12 years and inferring SSN min for SC25 to occur in 2020 or later (Wilson 2015, 2017).

SSN max values are observed to have generally increased from SC12 to SC19 and then decreased from SC19 to SC24, with an even-numbered-odd-numbered cycle preferential behavior apparent; i.e., in even-odd-numbered SC pairs, the odd-numbered following SC almost always has been the cycle of larger SSN max, true for five of six known pairs, with only SC23 failing in cycle pair SC22–SC23. In descending order of SSN max, the largest SC is SC19 (269.3), followed by SC21 (220.1), SC18 (214.7), SC22 (211.1), SC17 (190.6), SC23 (173.9), SC15 (173.6), SC20 (150.0), SC13 (142.2), SC16 (129.7), SC24 (113.3), SC12 (106.1), and SC14 (105.5). The mean SSN max measures 168.7 with $sd = 51.3$, and the median SSN max is 173.6. The four largest SCs—SC18, SC19, SC21, and SC22—all have the shortest rise time from SSN min to SSN max (3 years) and were among the shortest in cycle duration (10 years), in addition to all having SSN max >200.

In descending order of SSN min, the cycle with the largest SSN min is SC21 (18.4), followed by SC18 (16.1), SC20 (15.0), SC22 (14.8), SC23 (11.6), SC13 (10.4), SC16 (9.7), SC17 (9.2), SC19 (6.6), SC12 (5.7), SC14 (4.6), SC24 (4.2), and SC15 (2.4). The mean SSN min measures 9.9 with $sd = 5.1$, and the median SSN min is 9.7. For SC24, its SSN measured about 7.0 in 2018 (the 10th year of the ongoing SC), a value well within the range of previously observed SSN min values (2.4–18.4) and consequently indicates that SSN min for SC25 is near.

Figure 2 shows the annual variation of the corrected SSA for the interval 1875–2017 (thin line) and the estimated value for 2018 (dashed line, being about 24.4 millionths of a solar hemisphere) for SC12–SC24. Also shown for comparison are the occurrences of SSN min and SSN max using unfilled and filled triangles as before. As with SSN, the t statistic for independent samples is found not to be statistically significant ($t = -1.2227$). Also given is the inferred linear correlation coefficient r between SSA and SSN, having $r = 0.972$, inferring that >94% of the variance in SSA can be explained by the variation of SSN (or vice versa). The inferred regression equation is $y = -93.0 + 11.066x$, where y is the dependent variable SSA, and x is the independent variable SSN. The overall mean SSA is 830.9 millionths of a solar hemisphere, having $sd = 738.2$ millionths of a solar hemisphere. Unlike SSN, which typically appears to be more singularly peaked, SSA often appears to have multiple peaks over the SC (e.g., SC14, SC16, SC18, SC20, SC21, and SC22).

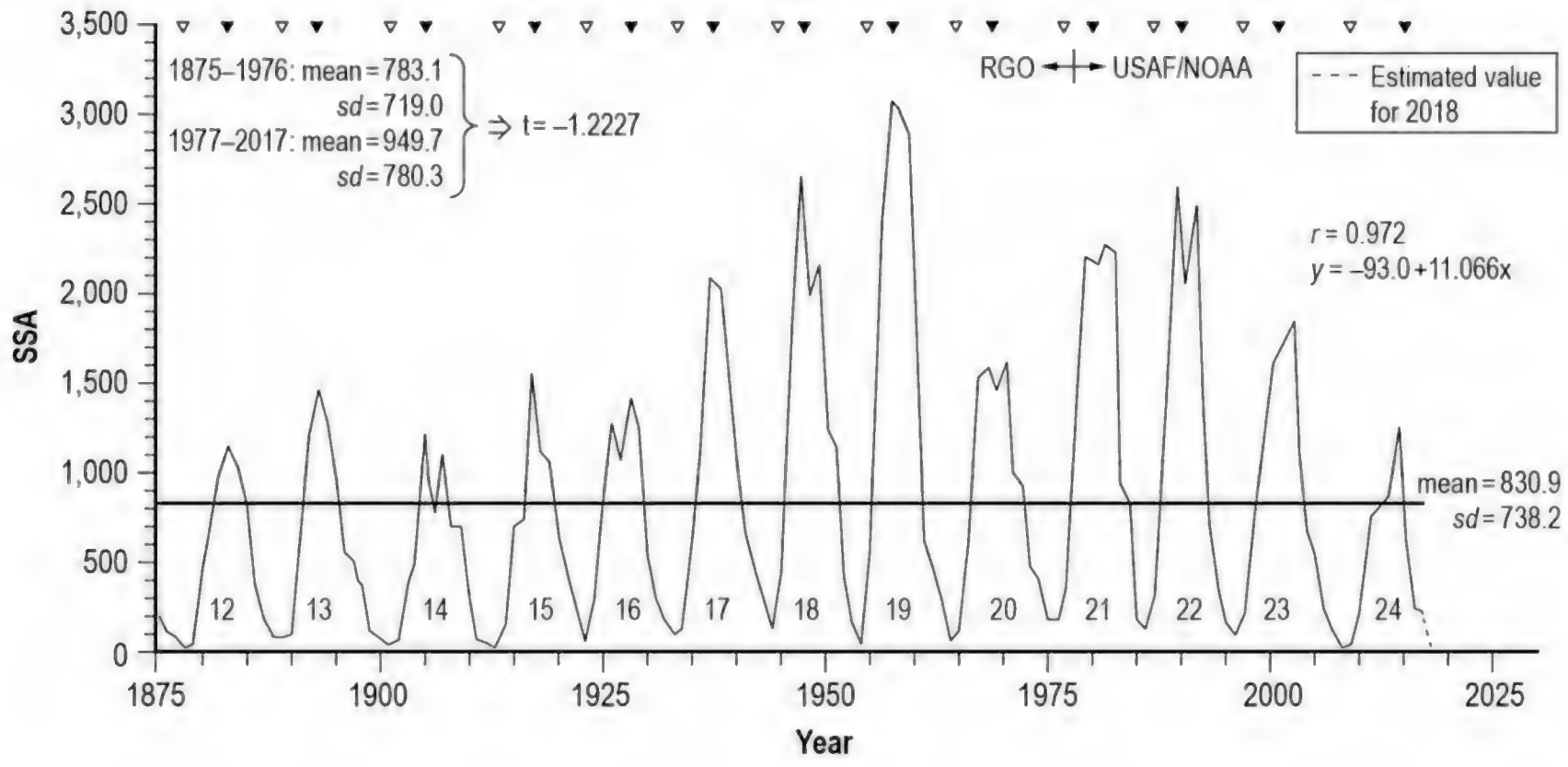


Figure 2. Variation of annual corrected sunspot area (SSA), sunspot cycles (SCs) SC12–SC24. The filled and unfilled triangles have the same meanings as used in Figure 1. The linear correlation coefficient r and inferred regression equation for SSA versus sunspot number (SSN) is shown. The t statistic for independent samples is given.

As with SSN max values, SSA max values are observed to have generally increased from SC12 to SC19 and decreased from SC19 to SC24—with the odd-numbered SC following the even-odd-numbered cycle pairs, almost always being the cycle of larger SSA max (true for five of six known pairs), with only SC23 failing in cycle pair SC22–SC23. In descending order of SSA max, the largest SC is SC19 (3,048.5), followed by SC18 (2,634.1), SC22 (2,579.2), SC21 (2,270.2),

SC17 (2,072.8), SC23 (1,828.7), SC20 (1,601.3), SC15 (1,533.9), SC13 (1,460.6), SC16 (1,388.9), SC24 (1,252.2), SC14 (1,195.9), and SC12 (1,148.9). The mean SSA max measures 1,847.3 millionths of a solar hemisphere with *sd* = 620 millionths of a solar hemisphere and the median SSA max is 1,601.3 millionths of a solar hemisphere. Close inspection reveals that 10 of 13 SCs have had simultaneous maxima of SSN and SSA, with only SC20, SC21 and SC23 having SSA max lagging SSN max by 2 years.

In descending order of SSA min, the cycle with the largest SSA min is SC21 (166.4), followed by SC18 (124.7), SC22 (124.7), SC17 (91.3), SC23 (81.9), SC13 (76.7), SC16 (54.7), SC20 (53.9), SC19 (34.6), SC14 (27.9), SC24 (22.8), SC12 (22.2), and SC15 (7.5). The mean SSA min measures 68.4 millionths of a solar hemisphere with *sd* = 48.2 millionths of a solar hemisphere and the median SSA min is 54.7 millionths of a solar hemisphere. (As previously noted, the estimated value for SSA in 2018 is 24.4 millionths of a solar hemisphere.)

Figure 3 displays the ratio of SSA to SSN, showing the yearly average SSA per unit SSN. Obviously, the ratio changes significantly over the SC (from about 3.1 to 13.7), usually being greatest near SSN max (e.g., SC12, SC14, SC18, SC22 and SC24) or later during the declining portion of the SC (e.g., SC13, SC15, SC17, SC19, SC21 and SC23). Only SC16 and SC20 had their greatest ratio prior to SSN max. The minimum ratio usually occurs concurrently with SSN min (e.g., SC13, SC15, SC16, SC19, SC20, SC22, and SC24) or just before or after SSN min (e.g., SC14, SC21, and SC23 had their minimum ratio 1 year preceding SSN min, while SC12 and SC18 had their minimum ratio 1 year after SSN min, and SC17 had its minimum ratio 2 years after SSN min). Interestingly, all odd-numbered SCs had their maximum ratio 1–5 years after SSN max, while all even-numbered SCs had their maximum ratio either concurrent with SSN max (e.g., SC12, SC14, SC18, SC22 and SC24) or preceding SSN max by 2 years (e.g., SC16 and SC20). The largest ratio measures 13.67 occurring in 1982 (SC21), which is larger than the 12.56 that occurred in 1959 (SC19, the largest amplitude SC, having SSN max = 269.3 in 1957).

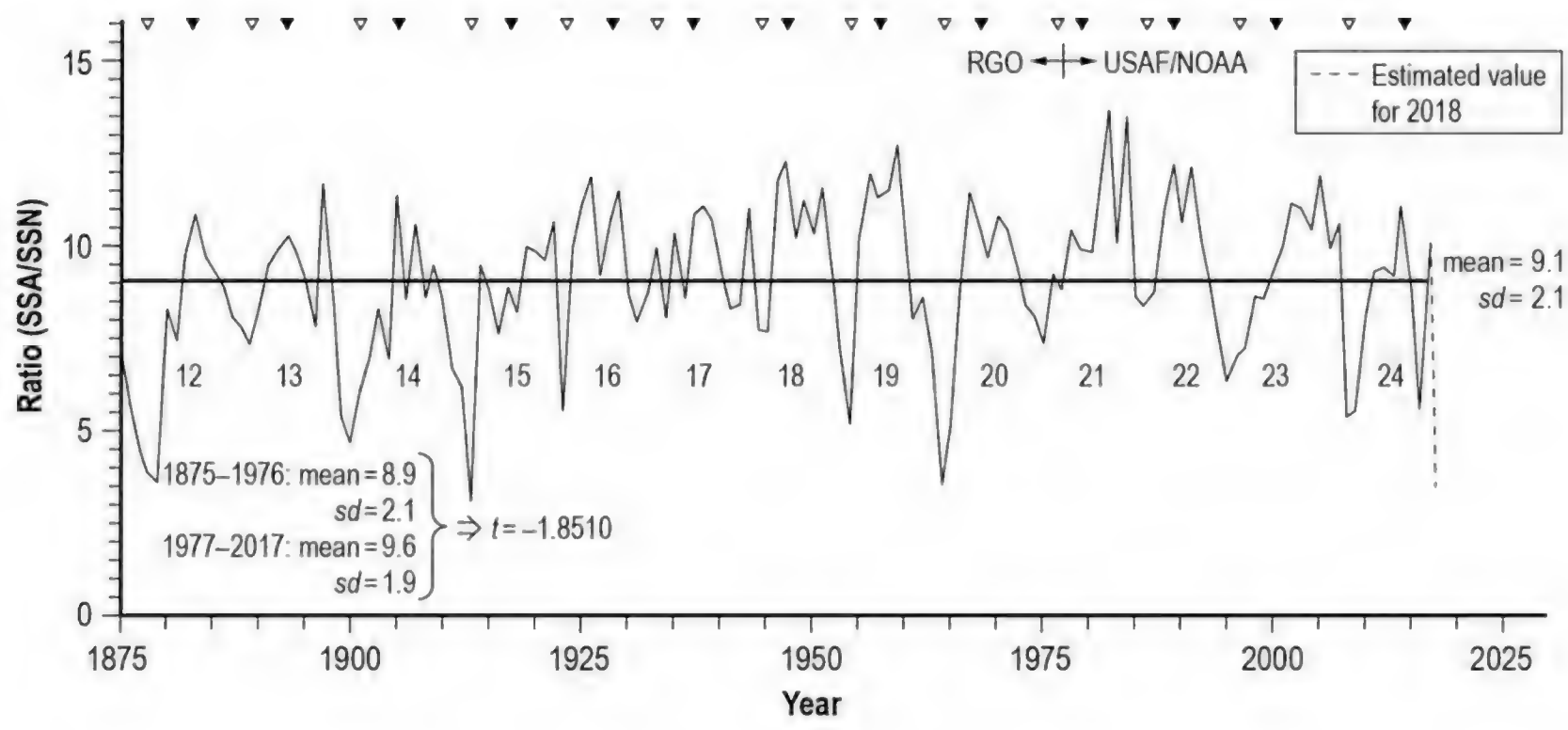


Figure 3. Variation of the annual ratio sunspot area/sunspot number (SSA/SSN), sunspot cycles (SCs) SC12–SC24. The filled and unfilled triangles have the same meanings as used in Figure 1. The *t* statistic for independent samples is given.

Figure 4 shows the annual variation of NARE. Recall that NARE is simply the number of sunspot areal entries per year in the SSA dataset. While NARE has the strongest correlation against SSN ($r = 0.982$, $y = 33.1 + 20.516x$), the t statistic for independent samples suggests that a statistically significant difference in the means between the RGO and USAF/NOAA intervals might exist, with the latter interval having more daily entries, on average, than the former. For all cycles, NARE min occurs concurrently with SSN min. For 8 of 12 cycles, NARE max occurs concurrently with SSN max (i.e., SC13, SC15, SC16, SC17, SC18, SC21, SC23 and SC24), while preceding by 1 year for SC20 and following by 1 year for SC12, SC19, and SC22 and by 2 years for SC14. On average, NARE measures about 1,726.0 entries per year (or about 4.7 entries per day) with sd = 1,336.1 entries per year. NARE spans 60 in 1913 (SC15) to 5,439 in 1979 (SC21). SC19, the largest SC in terms of SSN and SSA, had NARE max = 5,016 (1958), yet it was not the largest SC in terms of NARE. This seems to suggest that SC19 was large because it had a larger number of groups (NG) and/or a larger number of individual spots (NS) than SC21. (Recall that, by definition, SSN = 10 NG + NS and that a group is an active region.)

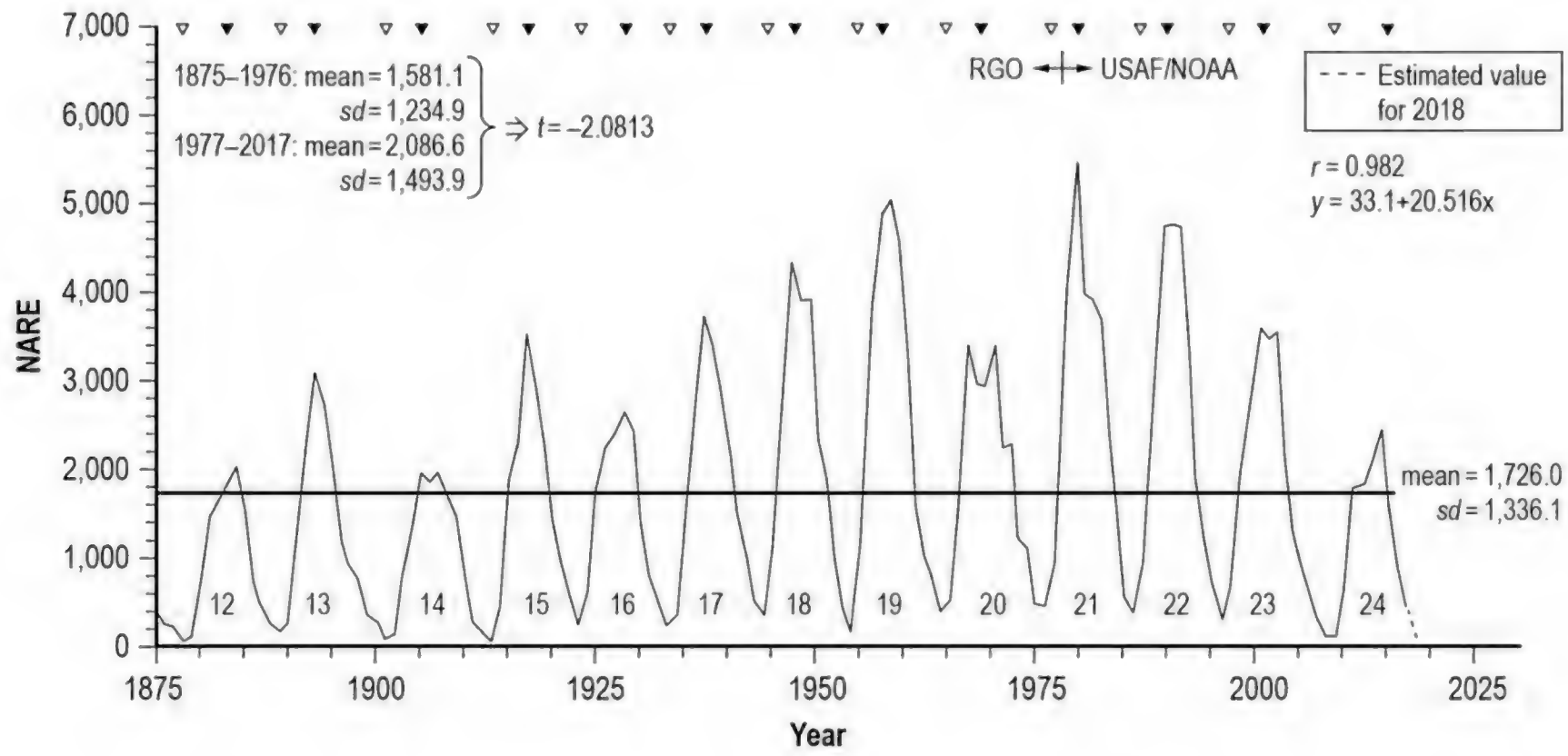


Figure 4. Variation of the annual number of active region entries (NARE), sunspot cycles (SCs) SC12–SC24. The filled and unfilled triangles have the same meanings as used in Figure 1. The linear correlation coefficient r and inferred regression equation for NARE versus sunspot number (SSN) is shown. The t statistic for independent samples is given.

Regarding NARE max, SC21 has the largest NARE (5,439), followed by SC19 (5,016), SC22 (4,751), SC18 (4,298), SC17 (3,705), SC23 (2,442), SC15 (3,510), SC20 (3,390), SC13 (3,071), SC16 (2,613), SC24 (2,442), SC12 (2,039), and SC14 (1,951). The mean (sd) of NARE max is 3,524 (1,115.7), and the median NARE max is 3,510. Regarding NARE min, SC21 has the largest NARE min (426), followed by SC22 (394), SC20 (390), SC18 (370), SC23 (306), SC16 (244), SC17 (225), SC13 (191), SC19 (166), SC24 (122), SC12 (81), SC14 (78), and SC15 (60). The mean (sd) of NARE min is 234.8 (131.6), and the median NARE min is 225. The value of NARE for 2018 is 161.

Figure 5 displays the annual variation of LAAR/MC. While LAAR/MC correlates only loosely against SSN, having $r = 0.695$ and $y = 923.7 + 10.792x$, it shares a somewhat similar

behavior with SSN, SSA ,and NARE in that there appears to be a general rise from SC12 to about SC18 and a decrease afterwards to SC24 (especially after SC22). The largest sunspot in the interval 1875–2018 occurred in SC18, designated region 1488063. It occurred on April 8, 1947, and measured 6,132 millionths of a solar hemisphere. For SC16, the cycle with the second largest LAAR/MC, region 986103, attained its maximum size on January 19, 1926, and measured 3,716 millionths of a solar hemisphere. For SC19, the largest SC of the modern era in terms of SSN and SSA annual values, its largest active region, designated region 1910900, occurred on January 8, 1959, and measured only 2,805 millionths of a solar hemisphere. Compared to the largest active region of SC18, the largest active region of SC19 is less than half its size.

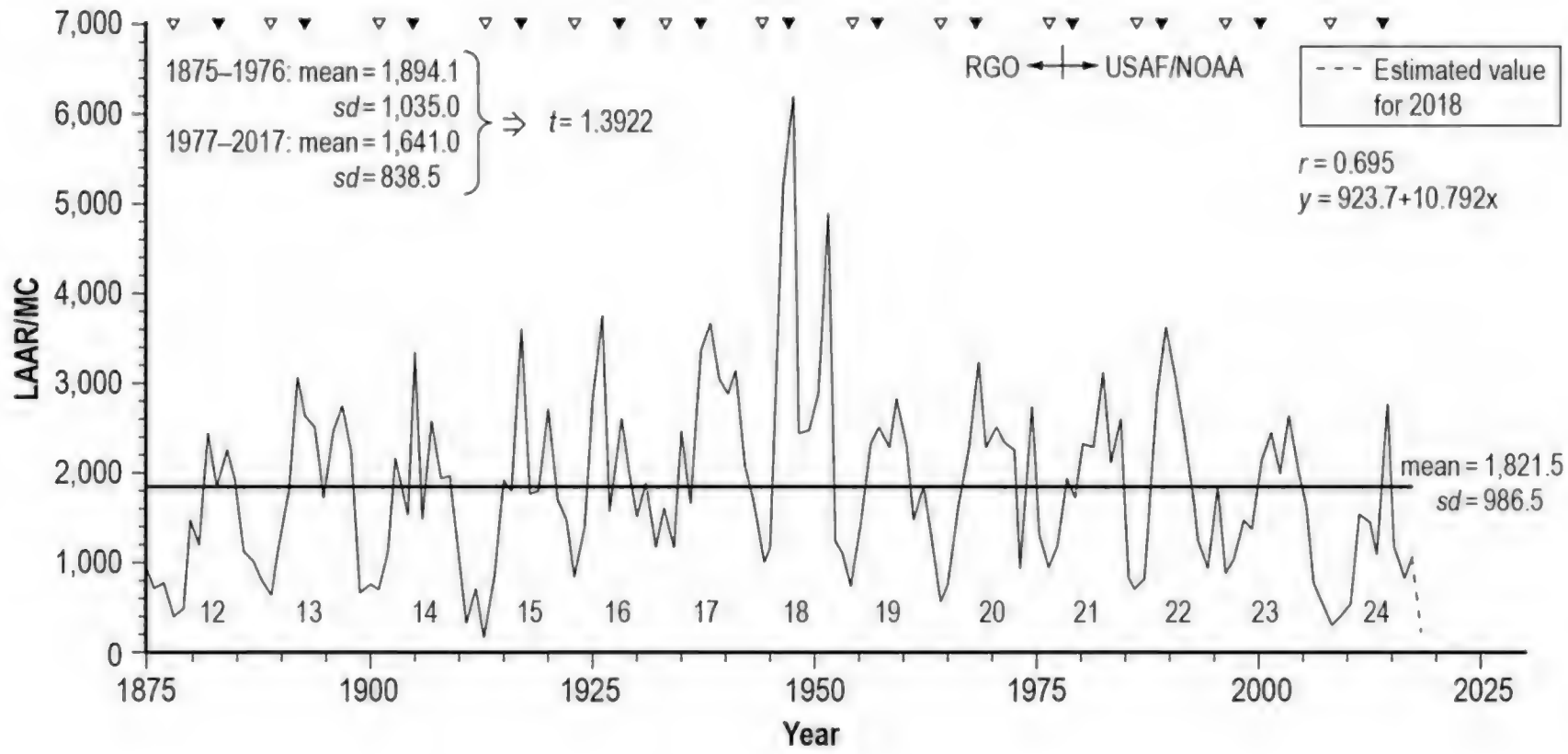


Figure 5. Variation of the annual largest area active region/magnetic class (LAAR/MC), sunspot cycles (SC) SC12–SC24. The filled and unfilled triangles have the same meanings as used in Figure 1. The linear correlation coefficient *r* and inferred regression equation for LAAR/MC versus SSN is shown. The *t* statistic for independent samples is given.

Overall, the mean LAAR/MC measures 1,821.5 millionths of a solar hemisphere (*sd* = 986.5 millionths of a solar hemisphere). Interestingly, SC24's LAAR/MC max is comparable in size to that seen in SC19 (2750 versus 2805). For LAAR/MC max, the progression from largest to smallest SC amplitude values is SC18 (6,132), SC16 (3,716), SC17 (3,627), SC22 (3,600), SC15 (3,590), SC14 (3,339), SC20 (3,202), SC21 (3,100), SC13 (3,038), SC19 (2,805), SC24 (2,750), SC23 (2,610) and SC12 (2,425). The mean LAAR/MC max measures 3,379.5 millionths of a solar hemisphere, with *sd* = 926.5 millionths of a solar hemisphere and a median equal to 3,202 millionths of a solar hemisphere. For 7 of 13 SCs, LAAR/MC max occurs concurrently with SSN max (i.e., SC13, SC14, SC15, SC18, SC20, SC22, and SC24). SC12 and SC16 had their LAAR/MC max 1and 2 years, respectively, prior to SSN max and SC17, SC19, SC21, and SC23 had their LAAR/MC max 1 (SC17), 2 (SC19), and 3 years (SC21 and SC23) following SSN max.

For LAAR/MC min, the progression from largest to smallest value is SC17 (1,155), SC18 (1,010), SC21 (937), SC23 (880), SC16 (831), SC19 (712), SC22 (700), SC13 (639), SC14 (638), SC20 (545), SC12 (402), SC24 (300), and SC15 (138). The mean LAAR/MC min measures 683.6

millionths of a solar hemisphere, with *sd* = 288.9 millionths of solar hemisphere and a median equal to 700 millionths of a solar hemisphere. For 11 of 13 SCs, LAAR/MC min occurs concurrently with SSN min. Only SC14 (2 years) and 17 (1 year) had their LAAR/MC min before SSN min. The value of LAAR/MC for 2018 (SC24) measures 240 millionths of a solar hemisphere.

Figure 6 shows the annual variation of MAE. MAE is simply SSA divided by NARE and then multiplied by the number of days in the year. As with LAAR/MC, there is only a loose correlation between MAE and SSN, having $r = 0.636$ and $y = 124.6 + 0.398x$. The mean MAE measures 157.8 millionths of a solar hemisphere, with *sd* = 40.4 millionths of a solar hemisphere. There is the perception that MAE was declining in value between SC12 and SC15, rising between SC15 and SC19 and declining again after SC19 (through, at least, SC24). Interestingly, MAE max occurred concurrently with SSN max for all even-numbered SCs, while following SSN max by 1–5 years for all odd-numbered cycles. The mean MAE max measures 210.4 millionths of a solar hemisphere, with *sd* = 19.5 millionths of a solar hemisphere and a median equal to 208.6 millionths of a solar hemisphere.

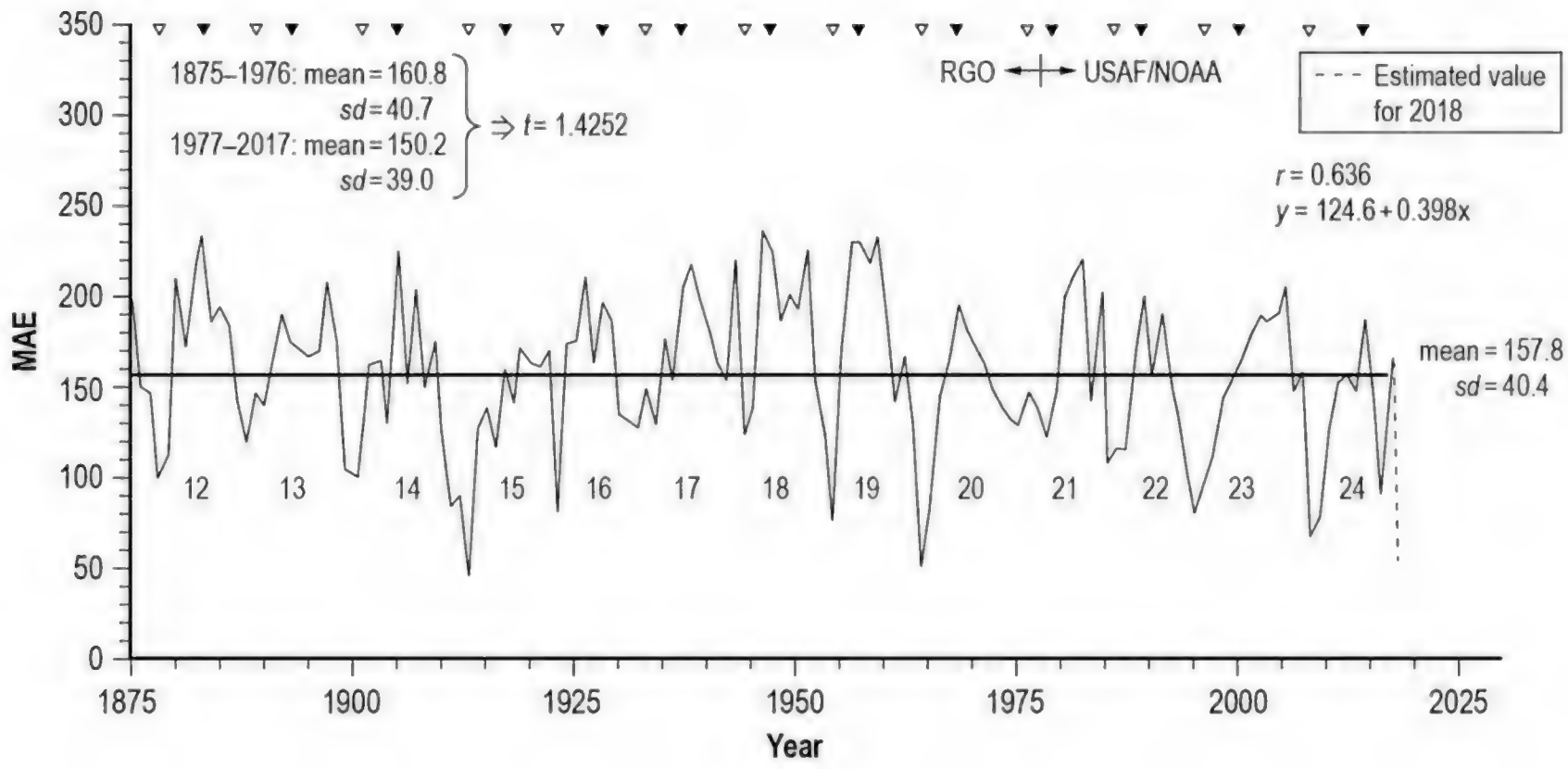


Figure 6. Variation of the annual mean area per entry (MAE), sunspot cycles (SC) SC12–SC24. The filled and unfilled triangles have the same meanings as used in Figure 1. The linear correlation coefficient *r* and inferred regression equation for MAE versus sunspot number (SSN) is shown. The *t* statistic for independent samples is given.

For MAE max, the progression from largest to smallest value is SC18 (234.6), SC12 (234.0), SC19 (232.3), SC14 (225.4), SC21 (219.8), SC17 (218.9), SC16 (208.6), SC13 (206.8), SC23 (203.5), SC22 (198.9), SC20 (193.9), SC24 (187.2), and SC15 (171.2). The mean MAE max measures 210.4 millionths of a solar hemisphere, with *sd* = 19.5 millionths of a solar hemisphere and median equal to 208.6 millionths of a solar hemisphere. For MAE min, the progression from largest to smallest value is SC17 (126.8), SC21 (123.8), SC18 (123.4), SC13 (121.4), SC22 (108.2), SC12 (100.0), SC14 (99.6), SC23 (82.4), SC16 (81.8), SC19 (76.1), SC24 (68.4), SC20 (50.6), and SC15 (45.6). The mean MAE min measures 92.9 millionths of a solar hemisphere, with

sd = 27.9 millionths of a solar hemisphere and a median equal to 99.6 millionths of a solar hemisphere. The value of MAE for 2018 measures 55.3 millionths of a solar hemisphere.

Figure 7 displays the annual variation of HLS. The overall appearance in the variation of HLS is that it was generally rising from SC12 through SC22 and declining afterwards. As with LAAR/MC and MAE, only a loose correlation exists between HLS and SSN ($r = 0.400$ and $y = 30.6 + 0.053x$). The mean HLS measures 34.9°, with $sd = 8.4°$. For HLS max, the progression from largest to smallest value is SC15 (59.5°), SC22 (58.0°), SC19 (50.3°), SC23 (50.0°), SC16 (48.0°), SC20 (46.1°), SC21 (45.6°), SC18 (42.9°), SC17 (42.2°), SC24 (42.0°), SC14 (40.9°), SC13 (40.5°), and SC12 (38.6°). The mean HLS max measures 46.5°, with $sd = 6.5°$ and a median equal to 45.6°. For HLS min, the progression from largest to smallest value is SC21 (20.1°), SC16 (29.3°), SC22 (28.0°), SC18 (26.1°), SC17 (25.6°), SC20 (25.2°), SC23 (24.0°), SC15 (21.9°), SC13 and SC19 (20.1°), SC14 (16.4°), SC12 (15.3°) and SC24 (15.0°). The mean HLS min measures 22.8°, with $sd = 5.2°$ and a median equal to 24.0°. The value of HLS for 2017 and 2018 measures 19.0° and 32.0°, respectively.

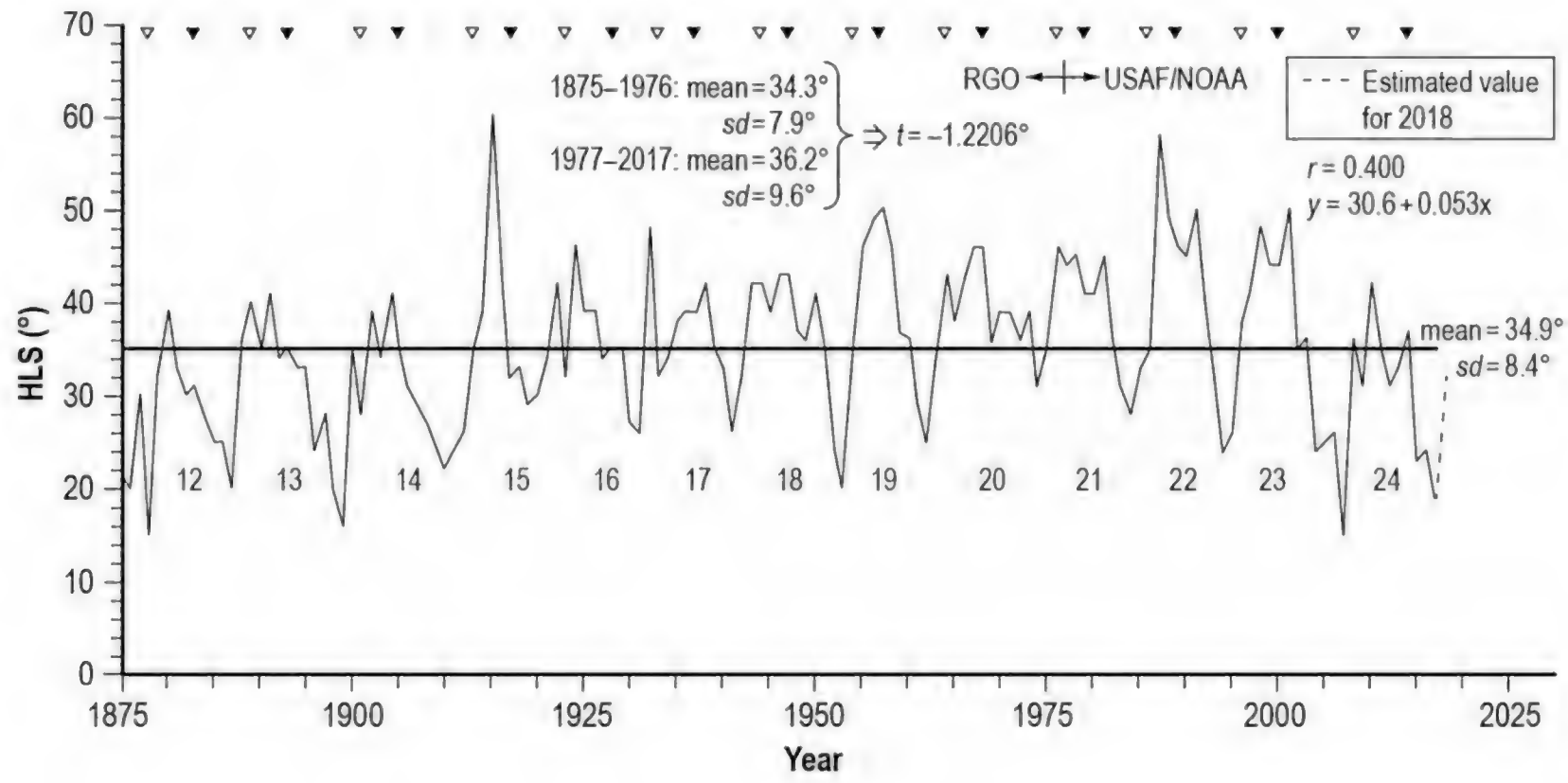
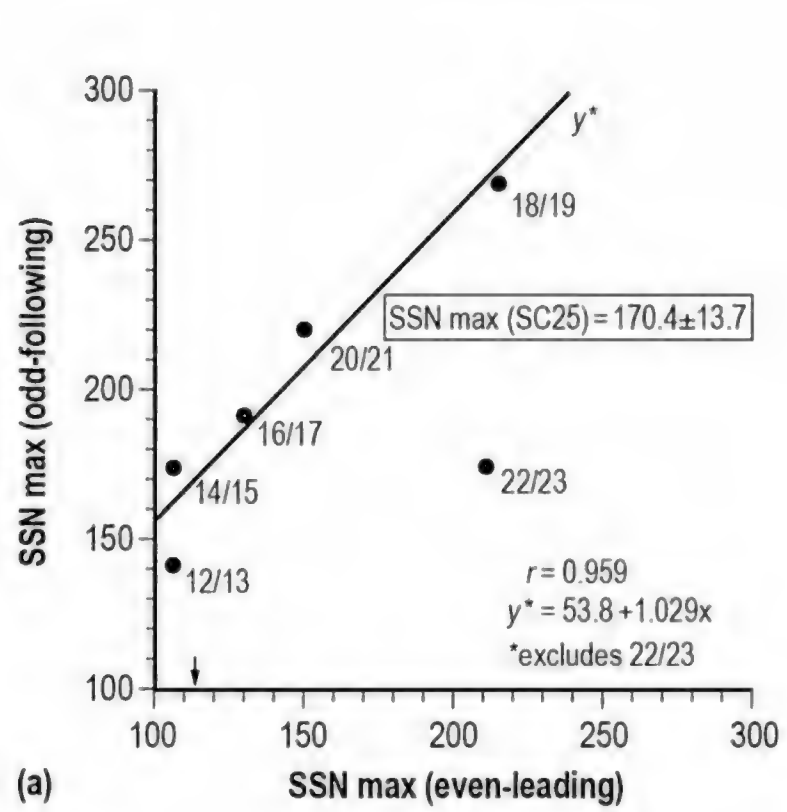


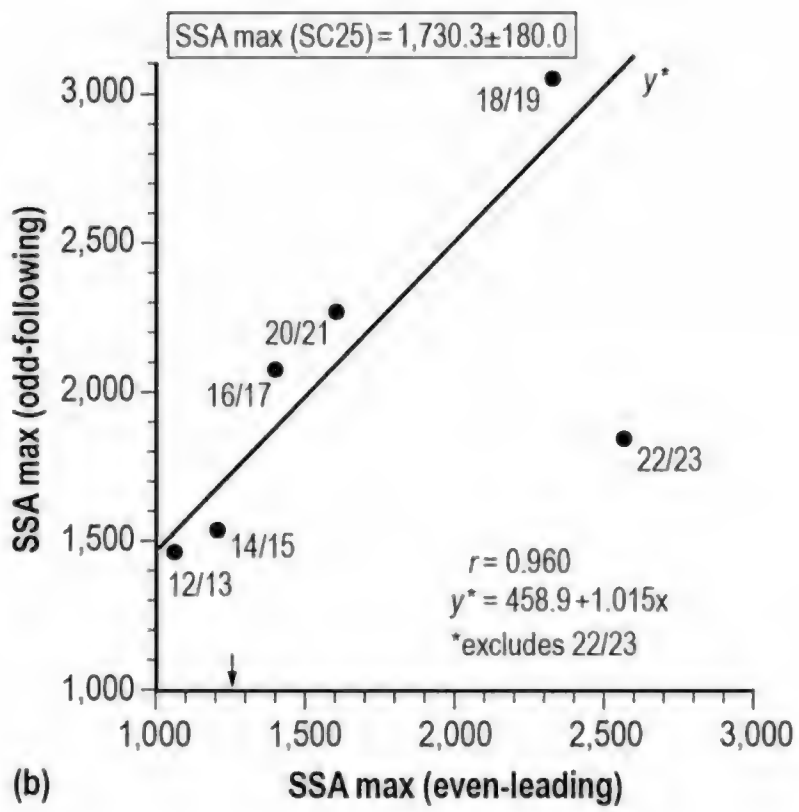
Figure 7. Variation of the annual highest latitude spot (HLS), sunspot cycles (SC) SC12–SC24. The filled and unfilled triangles have the same meanings as used in Figure 1. The linear correlation coefficient *r* and inferred regression equation for annual mean area per entry (MAE) versus SSN is shown. The *t* statistic for independent samples is given.

HLS max is found to almost always occur prior to SSN max. Only SC19 and 23 had HLS max either concurrent with SSN max (SC19) or after SSN max (SC23, +2 years). HLS max occurred 4 years prior to SSN max for SC24, 3 years prior to SSN max for SC12, SC16, and SC21, 2 years prior to SSN max for SC13, SC15, and SC22, and 1 year prior to SSN max for SC14, SC18, and SC20. Similarly, HLS min almost always occurs prior to SSN min. Only SC12 had its HLS min concurrent with SSN min. HLS min occurred 5 years prior to SSN min for SC17, 4 years prior to SSN min for SC16, 3 years prior to SSN min for SC15 and 18, 2 years prior to SSN min for SC13, SC14, SC17, SC20, SC21, SC22, and SC23, and 1 year prior to SSN min for SC19 and SC24. Now in the late stage of SC24, an HLS value indicative of a possible HLS min for SC25

appears to have occurred in 2017 (=19°) since the value for 2018 (=32°) is higher. Near SSN min, there is a change from lower latitude old cycle spots to higher latitude new cycle spots, where new cycle spots are differentiated from old cycle spots by means of their leading and following magnetic polarity. For even-numbered SCs, the northern hemisphere of the Sun has negative-leading and positive-following magnetic polarity (reversed in the southern hemisphere). For odd-numbered SCs, the leading and following hemispheric polarities are reversed. The overlap in old and new cycles about SSN min is about 1–3 years (Howard 1977).

Figure 8 illustrates the even-odd cycle effect for SSN max, SSA max, and NARE max. Given are the linear correlation coefficients and inferred regression equations, ignoring SC22/23. Located along the *x*-axis are arrows signifying the max values from SC24. For SSN max, the observed value of SSN max for SC24 (= 113.3) suggests that SSN max for SC25, the next SC, is expected to be about 170.4 ± 13.7, presuming that cycle pair SC24/25 will not be a statistical outlier (as SC22/23). For SSA max and NARE max, predicted values for SC25 are 1,730.3 ±180.0 millionths of a solar hemisphere and 3,775 ± 510 entries.





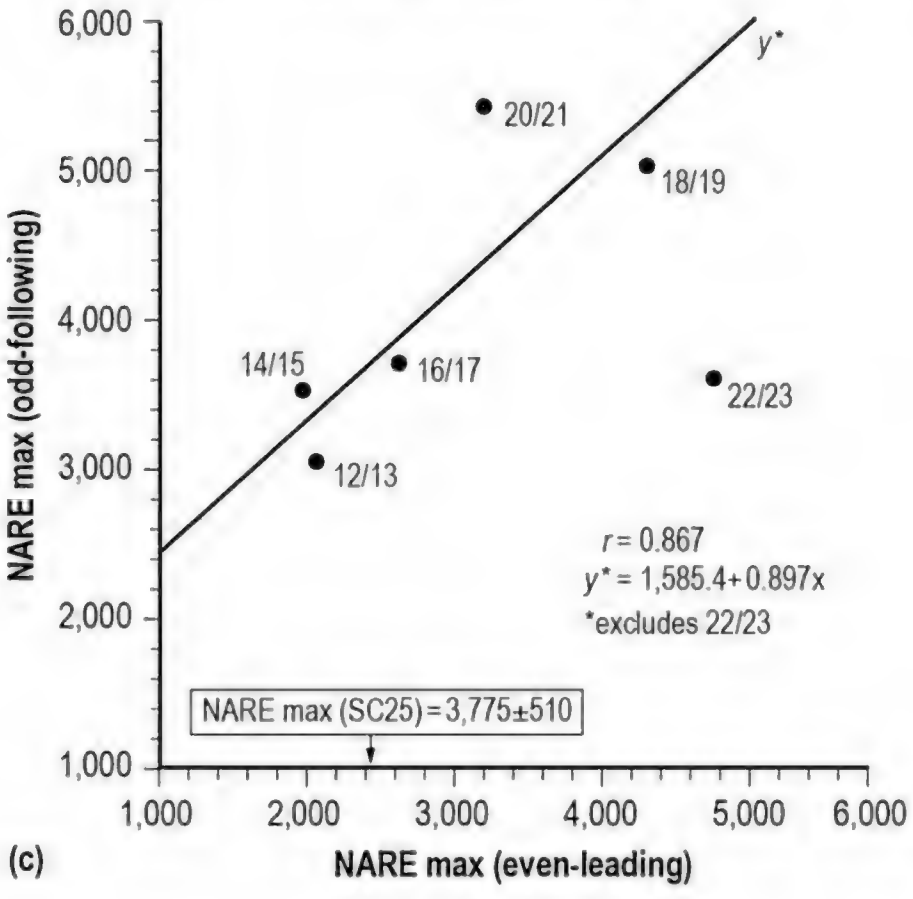


Figure 8. Scatterplots of (a) maximum sunspot number value (SSN max) (odd-following) versus SSN max (even-leading), (b) maximum sunspot area value (SSA max) (odd-following) versus SSA max (even-leading) and (c) maximum number of active region entries value (NARE max) (odd-following) versus maximum number of active region entries value (NARE max) (even-leading) for even-odd sunspot cycle pairs SC12/13–SC22/23. The linear correlation coefficient *r* and inferred regression equation is given, based on the exclusion of cycle pair SC22/23, which is a statistical outlier. The arrow along the x-axis of each scatterplot represents the max value for SC24. Based on the inferred regression and the SC24 parametric value, the ±1 standard error of measurement prediction interval for each parameter is given for the next SC, SC25.

Figure 9 shows the scatterplots and inferred relationships between SSN min, SSN max, SSA min, SSA max, NARE min, and NARE max against the HLS min values. HLS min is an intriguing parameter in that it generally occurs several years in advance of min values of SSN, SSA, and NARE and might be of predictive value for both the following min and max values of the parameters. For SSN min versus HLS min, $r = 0.772$ and $y = -7.3 + 0.75x$, inferring that SSN min for SC25 is expected to measure about 7.0 ± 3.2 (i.e., the ±1 standard error of estimate prediction interval), using HLS min = 19°, the observed value for 2017, indicated by the downward pointing arrow along the *x*-axis. Based on Fisher's exact test for 2×2 contingency tables (determined using the parametric medians, shown as the thin vertical and horizontal lines), the probability *P* of obtaining the observed result, or one more suggestive of a departure from independence (chance), is $P = 2.0\%$. In each of the charts, the numbers beside the filled circles refer to the solar cycle number. In particular, five of six solar cycles having HLS min <24° are expected to have SSN min <9.7, while six of seven solar cycles having HLS min ≥24° are expected to have SSN min ≥9.7. SSN is known to measure 7.0 in 2018, with a lower value expected for 2019. Hence, SC24 appears to now be experiencing an extended solar minimum, one which may last at least through 2019 and probably through 2020.

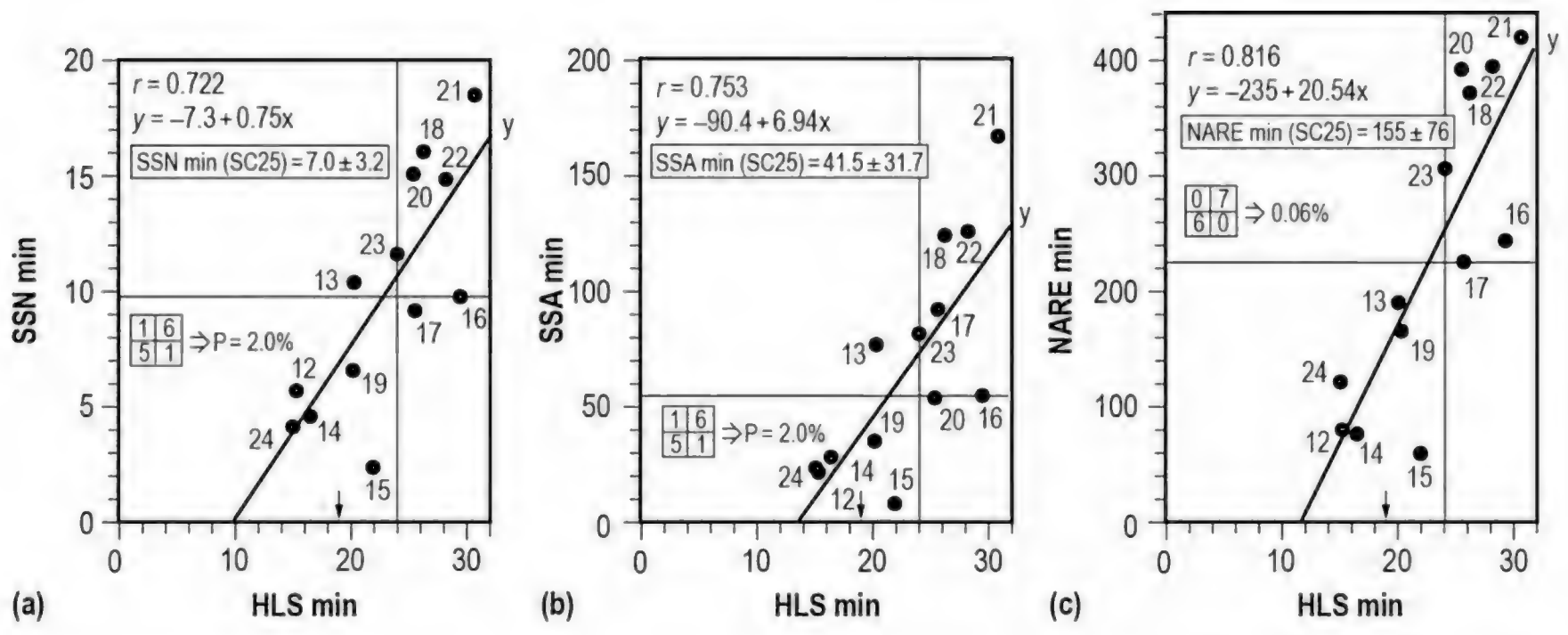


Figure 9. Scatterplots of (a) minimum sunspot number value (SSN min) versus the highest latitude spot minimum value (HLS min), (b) minimum sunspot area value (SSA min) versus highest latitude spot minimum value (HLS min), (c) NARE min versus HLS min, (d) maximum sunspot number value (SSN max) versus HLS min, (e) SSA max versus HLS min and (f) NARE max versus HLS min for SC12–SC24. HLS min is the smallest annual HLS value occurring either prior to or concurrent with the occurrence of SSN min. Shown are the linear correlation coefficients *r* and the inferred regression equation in each scatterplot, the probability *P* of obtaining the observed result, or one more suggestive of a departure from independence (chance), based on the 2×2 contingency tables (determined by the median values, the thin vertical and horizontal lines) and the estimated parametric values for SC25, the next SC. The arrow along the x-axis is the 2017 observed value of HLS (= 19°). For SSN max, SSA max, and NARE max, SC16 and SC19 have been excluded, since they appear to be statistical outliers.

For SSA versus HLS min and NARE min versus HLS min, $r = 0.753$ and 0.816 and $P =$ 2.0% and 0.06%, respectively. Based on the inferred linear regressions, SSA min and NARE min for SC25 are expected to measure about 41.5 ± 31.7 millionths of a solar hemisphere and 155 ± 76, respectively.

For SSN max, SSA max and NARE max versus HLS min—ignoring the values for SC16 and SC19 (statistical outliers)—strong linear correlations are inferred to exist ($r = 0.940$, $r = 0.875$, and $r = 0.953$, respectively). Using HLS = 19°, one expects SC25 to have SSN max = 136.2 ± 14.8, SSA max = 1,461.5 ± 261.2, and NARE max = 2,771 ± 330, assuming SC25 is not a statistical outlier.

Figure 10 displays the observed monthly spot latitudes (ignoring hemispheric notation), monthly number of spotless days (NSD), monthly SSN, monthly SSA and monthly NARE for the interval January 2016 through the end of 2018. As yet, there has been no occurrence of a high-latitude (≥30°) new cycle spot, which would be indicative of the approaching SC25 minimum. A new cycle spot was observed in August 2018, but it was located at low latitude (region 12720, 8° North). The spot (12699) located at 32° in January 2018 was a magnetically simple spot (i.e., a unipolar spot group). Near cycle minimum, new cycle spots at higher latitude become greater in number, while old cycle spots at lower latitudes become fewer in number, with the overlap of new and old cycles being about 1–3 years (Howard 1977).

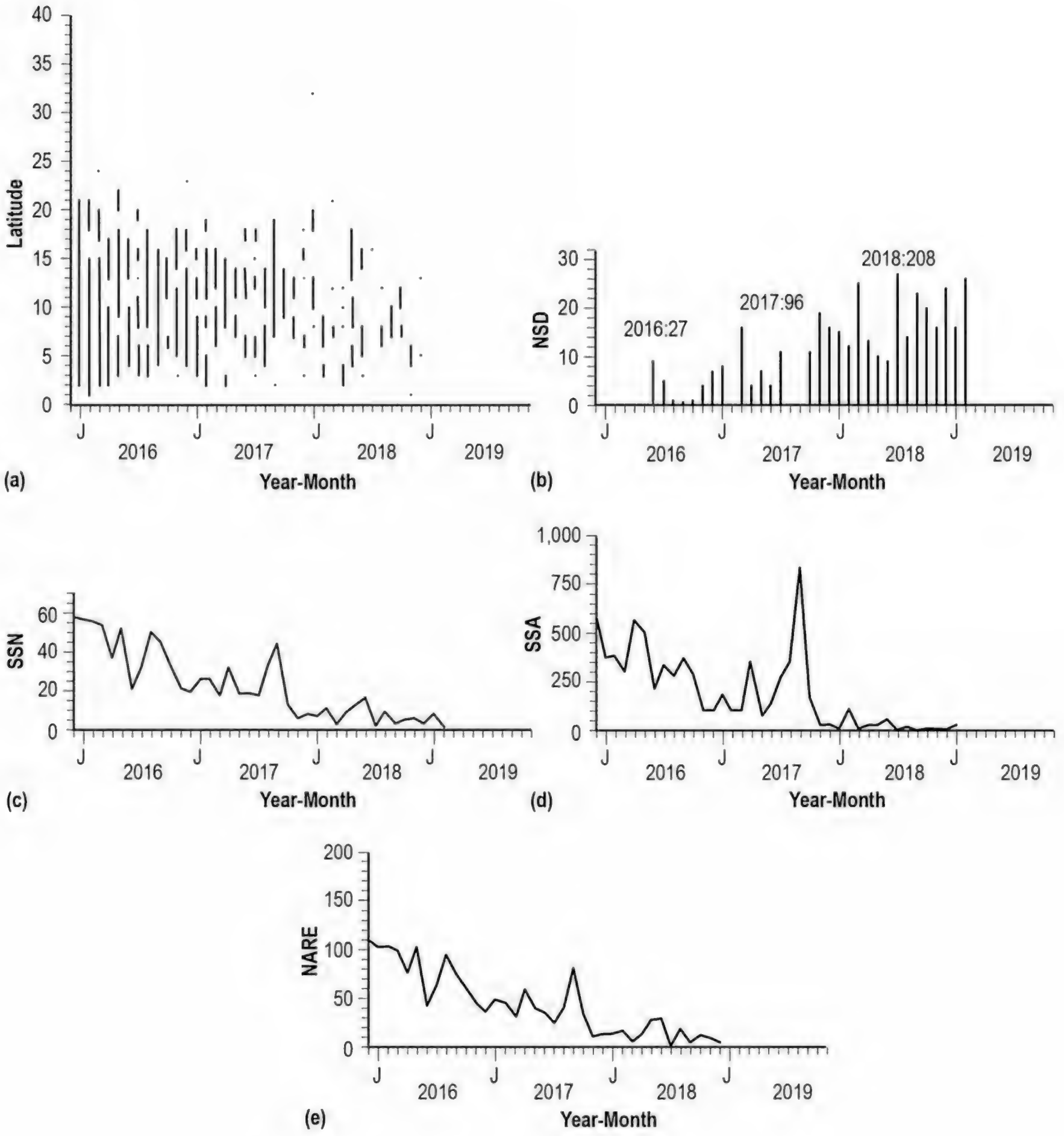


Figure 10. Plots of observed monthly values of (a) spot latitudes (ignoring hemispheric location), (b) number of spotless days (NSD), (c) sunspot number (SSN), (d) sunspot area (SSA) and (e) number of active region entries (NARE) for 2016–2018. Monthly values of SSN, SSA and NARE since late 2017 are indicative of sunspot minimum conditions. As yet, there has been no occurrence of new cycle high-latitude spots, which generally occurs near SC minimum. Old and new cycle spots typically overlap about 1–3 years.

In terms of NSD, there were 208 spotless days in 2018. In January and February 2019, there were 15 and 27 spotless days, respectively. SC15 had the greatest NSD (311) at SSN min (1913), followed by SC14 (287 in 1901), SC12 (280 in 1878), SC24 (265 in 2008), SC10 (261 in 1856), SC19 (241 in 1954), SC17 (240 in 1933), SC11 (222 in 1867), SC13 (212 in 1889) and SC16 (200 in 1923). SC18, SC20, SC21, SC22 and SC23 all had NSD <200 (Wilson 2017). NSDs have been increasing, with 10 months in 2018 having NSD ≥10 days per month and 4 months having NSD ≥20 days per month. Associated with this is a sharp reduction in monthly mean SSN, SSA and NARE. Late 2017 appears to mark the beginning of an extended period of solar minimum, one that could persist for 1–3 years or more.

In conclusion, this study (Paper I) has examined the variation of the annual means of SSN, SSA, NARE, LAAR/MC, MAE, and HLS for the years 1875–2017 and inferred correlations between selected parameters. Regarding SSN, one finds that the descent duration of all SCs SC12–SC23 has always been equal to or longer than their ascent duration, inferring that the present SC24 (ascent duration = 6 years) will have a descent duration ≥6 years and a SSN min-SSN min duration (i.e., ascent + descent duration) ≥12 years, suggesting that SSN min occurrence for SC25 will be the year 2020 or later. Generally, SSA and NARE closely mimic SSN, having $r \geq 0.97$, although SSA max is found to have followed SSN max by 2 years in SC20, SC21, and SC23. Interestingly, all odd-numbered SCs had their maximum ratio of SSA/SSN 1–5 years after SSN max, while all even-numbered SCs had their maximum ratio of SSA/SSN either concurrent with or preceding SSN max by 2 years. The largest SSA/SSN ratio (=13.67) occurred in 1982 (SC21). The largest NARE occurred in 1979 (=5,439, SC21). The largest individual spot group occurred on April 8, 1947 (SC18), measuring 6,132 millionths of a solar hemisphere. Interestingly, the largest spot groups occurring in SC19 (the largest SC in terms of SSN and SSA) and SC24 (the third smallest cycle in terms of SSN and SSA) are of comparable size (2,805 and 2,750 millionths of a solar hemisphere, respectively). Inferred correlations for LAAR/MC, MAE and HLS against SSN are not particularly strong, having $r < 0.7$. Interestingly, one finds that MAE max is observed to have occurred concurrently with SSN max for all even-numbered cycles, while following SSN max by 1–5 years for all odd-numbered cycles. Also, interestingly, HLS min is found to have almost always occurred prior to SSN min, with only SC12 having had concurrent occurrences of HLS min and SSN min. It appears that HLS min for SC25 may have occurred in 2017, measuring 19°. Based on the inferred strong correlations between minimum and maximum values of SSN, SSA, and NARE against HLS min, one predicts SC25, the next SC, to have the following ±1 standard error prediction intervals: SSN min = 7.0 ± 3.2, SSA min = 41.5 ± 31.7 millionths of a solar hemisphere, NARE min = 155 ± 76, SSN max = 136.2 ± 14.8, SSA max = 1,461.5 ± 261.2 millionths of a solar hemisphere, and NARE max = 2,771 ± 330. Based on the inferred even-odd cycle preferential behavior, assuming SC25 is not a statistical outlier, one predicts SSN max = 170.4 ± 13.7, SSA max = 1,730.3 ± 180.0 millionths of a solar hemisphere and NARE max = 3,775 ± 510 for SC25. SC24/25 appears to have begun an extended cycle minimum beginning about November 2017. As yet, there have been no observed high-latitude (≥30°) new-cycle spots, something which generally heralds the impending onset of the new solar cycle.

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ATTACK OF THE ICE ALIENS: A TRANSDISCIPLINARY PHYSICS LESSON

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ABSTRACT

While a deep understanding of physics is essential, a productive physicist also exhibits mastery of mathematics and computer science. Accordingly, students benefit from instruction that seamlessly integrates multiple disciplinary practices. One body of research holds that the more the investigative problem transcends disciplinary lines, the higher its educational value. This study's curriculum design explores the hypothesis that students engaged in a lesson that transcends disciplines will experience a higher level of learning. The setting of this transdisciplinary lesson is a forensics investigation to determine the time of death of a hypothetical Ice Alien. The assessment was designed to be in the same spirit as the lesson. The research team measured the students pre- and post-ability to think abstractly about the problem and to generalize its solution to other problem situations. Most students showed some indication they had learned to think about the problem at a higher level, some, in general terms, and some were able to encapsulate the general problem situation or process into an abstract object that they then applied to a novel problem situation.

Keywords: Interdisciplinary collaboration, physics education, forensics, python programming, rate of change

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INTRODUCTION

While it is obvious that a physicist possesses a deep understanding of physics, it is also implicitly understood that the successful work of the professional physicist demands a wide range of skills from other disciplines including mathematics and computer science. For example, software needed to solve a given problem may not be available "off the shelf", and the scientist must recognize and recover relevant mathematical equations and write the code that will implement them. Sadly, the trickle down of this logic to schools falls short. Physics, math, and computer science are often encountered in schools as silos of knowledge rather than interwoven, interdependent pursuits. Discipline specific language discourages collaborative efforts, and in fact, students do not recognize a problem that occurs in multiple classes, as it is cloaked in different notation, variables, and terminology. For decades educators and policy makers have seen that an interdisciplinary approach is an efficient, engaging, and productive response to the gap between schools and careers in science. In spite of this, curriculum that fits across disciplines has not widely appeared. This sloth-like response must be remedied to respond to the needs of today's fast-paced, innovative, and highly technological work force.

Motivation for the Project

Interdisciplinary curriculum has occupied curriculum reform documents for years. Early on, it was identified as the number one priority in a curriculum poll administered by the Association for Supervision and Curriculum Development (ASCD). Those polled included Chief State School Officers and deans of schools of education, Jacobs (1989). In fact, it may be helpful to go beyond interdisciplinary, to transdisciplinary curriculum. The idea is that the lessons or curriculum transcend the disciplines involved so that students think in terms of the overall problem situation rather than a specific disciplinary approach. This is not a new curricular idea. Jean Piaget introduced the term transdisciplinary in the early seventies, calling for a unity of knowledge across the disciplines.

Transdisciplinary research has already gained a foothold in the social sciences and humanities and it is making inroads with researchers in science and engineering; Ertas,Tani & Maxwell (2000); Tejedor, Segalas & Rosas-Casals (2017); Stokels, (2006). When seen as a successful framework for educators as well, the hope is that transdisciplinary curriculum will shape future science education and make a way to the synthesis and generation of new intellectual tools and techniques.

Transdisciplinary curriculum is a cooperative undertaking, that originates with a problem outside of or above individual disciplines that calls on individual disciplines for its solutions; Meeth (1978). A helpful metaphor for this approach can be found with the 20th century British philosopher Lionel Elvin. He described the current educational journey as a walk in nature where the hiker spends "three quarters of an hour only with flowers and in the next only with animals (p. 29)". He proposed a more organic approach to the learning adventure where the hiker is immersed in the totality of the forest, Elvin (1977). In her book chapter in *Interdisciplinary Curriculum* (1989), Jacobs (1989) stays in character adding you can still pick up a flower and study it closely, but the difference is that you come to the study of the flower with a perspective about the patch of woods where it

originated. This simple organic approach to curriculum development needs a spirit of cooperation among disciplinary experts to compose the forest scape.

The lesson in the present study was developed by a team of two physicists, two mathematicians, two computer scientists, and two high school math and science teachers. Following Meeth (1989), the problem situation was developed outside or above the disciplines of physics, mathematics, or computer science. Care was taken to find common language and notation, so that work could flow seamlessly between the disciplines. The solution ultimately required students to apply tools and techniques from each discipline. This synthesis forms new tools and techniques according to Tejedor,et al (2017).

In the Ice Alien Lesson, true to the imagery in Jacobs(1989), the students encountered physics, math, and computer science integrated "in the wild", but also learned to take up each "flower" for closer examination. Physics was examined in a discussion of the methods of estimating time of death by measuring physical quantities. Math was lifted out of the physical problem and identified as slope and x-intercept. Computer science provided tools to explore the mathematical behaviors and to make predictions in the physical world.

It is hoped that this lesson will inspire school teachers to look for opportunities to engage in a transdisciplinary approach and to partner with colleagues in other disciplines to ensure the material in each discipline is recognizable, so that students start to look for the math in physics class, the physics in computer science class, and so on. This lesson was intentionally developed with this goal in mind.

In order for the students and teachers to be prepared to conduct the investigation, the teacher must discuss the physics, mathematics, and computer science foundations for the lesson, obtain the required equipment, install the Python software, and identify the curriculum standards that are met by the lesson for reporting purposes. Section 2 includes a discussion of preparations and the steps involved in each part of the lesson for the activity and the lesson outcomes, and Section 3 discusses the evaluation of the effectiveness of the Ice Alien activity. Section 4 contains conclusions and future work.

A TRANSDISCIPLINARY LESSON

The setting for this lesson was an Ice Alien crash site. Students were tasked to determine the time of death of four Ice Aliens based upon the amount of ice melt measured at two different points in time (Physics). This provided the student two points in which the rate of change could be determined (Physics, Mathematics). Prior to collecting data in the actual Ice Alien experiment, students wrote computer programs to explore rate of change. The programs allowed students to view time versus volume iteratively (Computer Science). They explored slope, developed time-volume (t,v) ordered pairs, and plotted the ordered pairs using Python graphics (Computer Science, Mathematics). The Python lesson incorporated a discussion of the concepts of slope, y-intercepts, and x-intercepts (Mathematics) and relating them to t-v pairs (Physics). Students recorded their observations and calculated their estimates of times of death of each alien, these were compared to the actual time of death (when the ice started to melt). Error analysis was used to determine the best estimates. The lesson immersed students in the problem, rather than a discipline specific

pursuit, e.g., loops or slope, and students experienced the interdependency of Physics, Mathematics, and Computer Science in a seamless environment.

PREPARATIONS FOR THE LESSON

Conceptual Preparations

In order to begin to understand the experiment, the students must first be able to understand the underlying physics of the experiment, in this case, what a phase change is, and the thermodynamics of melting and thus the generation of the water that is used to measure how long the alien has been dead. The teacher should review the states of matter, namely solids, liquids, and gases, and review how differences in temperature affect the rate of melting or boiling of a substance. The teacher may also choose to review, if appropriate, the effect of temperature on the speeds of atoms and molecules.

The Ice Alien project depends upon the thermodynamics of melting. Ice at a given temperature will absorb energy at a rate determined by the ambient temperature, the surface area of the ice, and other factors such as movement of air. When an ice cube melts in air, a thin layer of water forms which insulates the ice and slows the melting. Air currents can evaporate this water, and if humidity is high, the rate of evaporation can be decreased. However, if the environment of the room is held constant, a linear increase in the temperature of the ice is expected up to 0°C, when the phase change from solid to liquid occurs. The energy, Q, to change the temperature of ice by temperature ΔT is given by

$$Q = mc\Delta T$$

Where m is the mass of the ice, c is the specific heat, and ΔT is the change in temperature; Serway and Jewett (2014). At this point, the ice will melt at a constant temperature and turn into a liquid, thus undergoing a phase transition from solid to liquid. To melt the ice completely the energy required is given by

$$Q = mL$$

Where m is the mass and L is the latent heat (Serway & Jewitt 2014). How fast this energy is transferred depends on many factors, including the temperature difference between the room and ice, as discussed above.

If the environmental conditions are held constant, there should be a constant amount of ice melting with time. The plot of the volume of water melted should therefore have a time at the beginning near zero volume while the ice heats to 0°C and for the water to bead to the point where it runs off the ice to be collected. This should be followed by a time of relatively linear increase in the volume of melted ice. We were concerned that Newton's Law of cooling might apply in this situation and would create a non-linear function for the collection of the water and would require calculus to describe to students. This would be beyond the level the students and teachers were prepared for in this lesson. As a result, the experiment described was run at various temperatures and the

collection of the water measured and plotted. The result of these experiments was that the water collected initially started slowly, and then became linear. The rates of collection for higher temperatures was greater. As a result, we were satisfied that our simplifying assumption of a linear rate of collection of the water collected was valid. We do not expect the temperature to vary in the classrooms over the time required to run the experiment.

The goal of the Ice Alien project is to push students to move from a low level, basic understanding of linear functions to a more sophisticated, deeper knowledge of its application. Too often, students ask "When will I use this?" truly wanting an understanding of where algebra is used in the real world. Although forensics is not likely to investigate the death of any ice aliens, this project gives students a chance to apply knowledge of linear applications, intercepts, and rate of change to solve a problem in the classroom and experience success. This lesson was prepared for an Algebra II with Trigonometry class. It was used at the midpoint of the Linear Chapter after a thorough review of slope, x-intercepts, y-intercepts, rate of change, and the slope-intercept equation.

Models used in review include algebraic expressions, graphs, and tables. The Ice Alien activity allows students to make a connection to the real world for what rate of change and the x-intercepts and y-intercepts could represent. It further pushes them to expand the linear concepts outside of the x-y coordinate plane to investigate time-volume relations, and other concepts they will encounter in physics, business, and many other applications. Before the experiment, graphs were used to help students conceptualize what a linear graph might represent, as shown in figure 1.

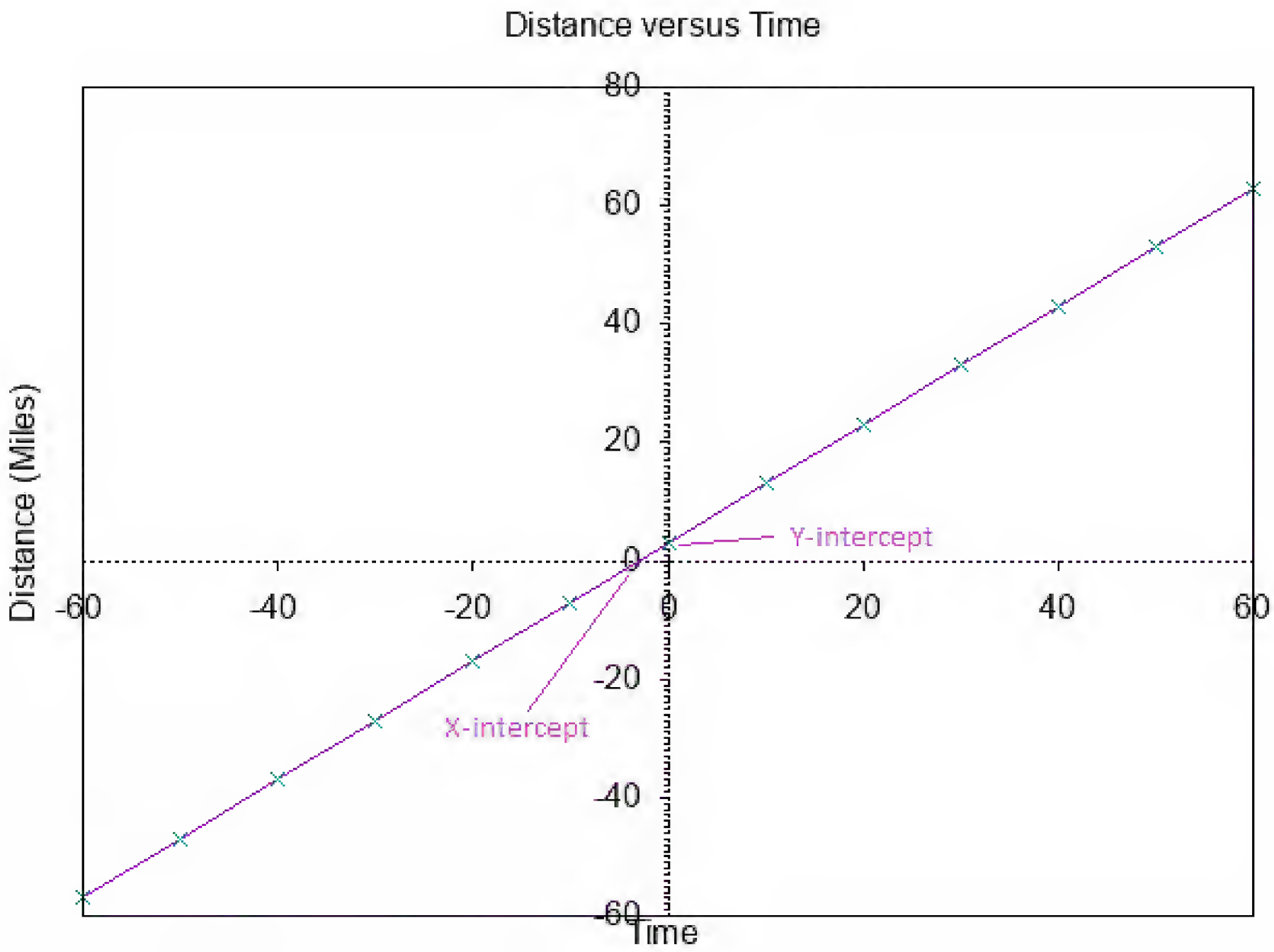


Figure 1. Linear graph with time-distance axes.

Students were questioned about what the x-intercepts and y-intercepts measured and were asked to reason out what the slope represents. Unit analysis was also applied to deepen understanding of rate of change.

To utilize this knowledge, students were given the following scenario with figure 1: "At time = 0, I glance at the odometer and I am 3 miles from home. How fast am I driving, assuming a constant speed? How long ago did I leave home? If it is12:22 pm, what time did I leave?" This discussion led into the physical representations on the graph of the key elements beyond the x-y graphs students are most often exposed to in high school math classes.

Similar scenarios were laid out for discussion such as a bowl of ice cream found on the counter. Given the melting rate, can students figure out how long it has been out of the freezer? These situations give context to the interpretation of negative time, since the question posed is how long ago the event occurred. Often negative time is dismissed. Such examples expand traditional reasoning of linear graphs.

Since the introduction to the Python IDLE environment and introduction to Python Programming takes place as part of the lesson, no computational preparation or review is required prior to the start of the lesson.

Materials and Setup

To conduct this activity, Python should be installed on the machines prior to the start of the lessons. Python 3 is used for the sample code given in this paper. For situations when students have tablets, rather than individual desktops, a web-based Python interpreter may be used. Prior to each lesson, teachers should be sure the selected web-based version has the Turtle library and can draw graphics. The latest download of Python 3 can be found at python.org.

The following materials are required for the Ice Alien experiment for four crash sites

1. 4ea - 4" ring clamp and stand (roughly 20" high)
2. 4ea- 4-6" mouth large plastic funnel
3. 4ea- 250 ml Graduated cylinder
4. 1 set of Tovolo Monsters (Alien) Ice Pop Flexible Silicone Molds (alternately solo cups could be frozen to represent the alien)
5. 1 set of four colors food dye (red, blue, green and yellow)
6. A large bag of small cubed or crushed ice
7. Access to a timer and clock.

The Ice Alien popsicles, or frozen Kool-aide in paper cups, should be frozen the night before the experiment. The four popsicles were in four different colors, so that each crash site station could be identified by its color.

Ninety minutes before students arrived, the stations were set up, with the melting beginning at randomly spaced intervals. The teacher should record the time of each alien's "death". This time is compared with the students' calculated results on Day 4. Aliens were packed with ice to ensure there would be sufficient water volume for the duration of the experiment (figure 2).

Figure 2. Ice Alien setup.

As the aliens melt, additional ice may need to be added to maintain uniform melting. Students will also need to have access to a timer to record the time at the initial volume reading and the time of the second reading.

DESCRIPTION AND INTERPRETATION OF THE LESSON

The activity can be done in three to four classes, depending on the length of a class period. Since this particular execution of the activity took four days, this paper will describe the activity over four days. We view the activities as a single lesson, given over several class periods, rather than the classes being separate from one another. The first three lectures are designed to introduce the students to the skills that they need to do the final analysis of the time of death of the ice aliens. The first three classes are given as direct instruction, with the instructors going over material and students doing discussion, coding, and mathematical exercises. The final class is inquiry based, and the students are free to solve the problem in teams as they see fit, with instructors there to guide and offer advice and suggestions. Since the ultimate goal is the ice alien investigation, the exercise is ultimately inquiry based. The first class goes over the physics involved in the activity and a brief introduction to Python. The second class focuses on the Python Turtle Graphics package and how to draw lines with ordered pairs, specifically drawing the x- and y- (or t- and v-) axes, generating x and y (t and v) ordered pairs in the printing of a table, and drawing the lines using the ordered pairs generated by the loop in the Python program. Simple linear equations are used to introduce the students to discussing the interpretation of the meaning of slope and the x- (i.e. time) and y- (i.e. volume) intercepts. The third day extends the work from the second day by exploring additional linear functions that have a negative t-intercept. For each equation, the table and graph is output from the program and the mathematical concepts are discussed and explored. The final class is when the Ice Alien experiment is actually conducted. Students collect data, and the time of death is estimated, followed by a review of the activity and discussion of how accurate the results are and what possible improvements might make it more accurate. We discuss the four parts of the lesson here.

Class one: Introduction to Forensics, Introduction to Python

Students should first be given a reminder of how changes in various objects and quantities can be used to determine when events occur. We cover the following principles of forensics in our introductory lesson. A good hunter or tracker can use their knowledge of animal tracks to estimate how long ago an animal passed through a location. Knowledge of the gas mileage of your car can tell you how often you will need to refill on a road trip.

Forensics is the study of dead organisms to determine things such as cause and time of death. Most people have a body temperature of about 37 degrees Celsius. When a person passes away, the body will usually start to cool down to whatever the background temperature happens to be. For a few hours there is little cooling due to bacterial activity, and then after about 3 – 4 hours the body will cool at about 1.5 degrees Celsius per hour for about six hours; Choudhary (web). The cooling then slows to between 0.6 to 1.2 degrees Celsius per hour. This process is called *algor morti;* Choudhary (web). Coroners can determine how long a body has been cooling down by knowing

the ambient temperature, the body's actual temperature, and having a set of tables relating the rate of cooling with the body's mass and temperature. Factors such as what the person was wearing and weather are also accounted for Choudhary (web). Plots of temperature versus time are called cooling curves, and can be used to determine the time of death of a body. These are measured in controlled conditions and are very accurate.

In our experiment, a member of an alien race that is made of ice has crashed and been discovered, and the investigators need to use what is known about the melting of ice to determine the time of death. The Ice Alien is placed in a funnel with additional ice and the water is collected in a volumetric flask. The temperature and other conditions of the room are considered unchanged since the time of the crash. As a result, we expect the amount of water being melted to have a fixed rate of change over time. If the investigator measures the amount of water at the beginning of the experiment, and then some time later, then the slope and x-intercept of the curve can be determined using software written by the scientist. This tells the time since the crash took place, and can be used to get the time of the crash.

Once these principles were discussed, a high level introduction of programming and Python was given to the students. The goal is not to teach programming or Python outside of what is needed to explore the mathematics and physics concepts being taught.

In programming, there are three major programming constructs that are often used to assist in problem solving: sequence, selection, and iteration. Sequence is the order in which statements of a program are executed. In Sequence, statements are executed once in a linear fashion. With Selection, some statements are executed based upon some condition with the current state of the program. With Iteration, some statements are repeated based upon some condition with the current state of the program. Students are given the example of an ATM machine. Examples of sequence would be 1. Enter your card, 2. Enter your PIN. Both instructions must happen without condition. Following these instructions, we see an example of sequence. At this point, the usual ATM interface will ask what you want to do next, withdraw from checking, withdraw from savings, check balances, etc. The user will make one selection and the code for that one selection will be executed. At the end of a given transaction, the ATM would prompt the client for another transaction. If yes is chosen, then the menu repeats itself. These constructs are some of the basics of programming.

A computer has 4 basic operations that students must know: input, output, processing, and storage. Input is gathered from a user and brought into storage so processing can occur, then any results to be given to the user is outputted. We began our Python introduction with output. The print statement will print what is in the parentheses, then print a newline after the output. So, to print the number 5, we would use:

```
print(5)
```

We then asked students to print the numbers 1-5 using print statements. They would proceed by doing the following:

Code	Output
`print(1)`	1
`print(2)`	2
`print(3)`	3
`print(4)`	4
`print(5)`	5

We motivated iteration by showing that extending the table to 100 would cause a repeat of the print statement 95 more times. We developed the loop using a flowchart, then introduced the following code to produce the first column of a table:

```
t = 1
while (t< 6):
     print(t)
     t = t + 1
```

We then discussed how t, represents time and starts at 0, increases by one after each print, then stops when it reaches the upper bound. Next, the concept of volume was introduced and represented in the second column as shown below:

Code	Output

`print("t", "v", sep = "\t")`
`t = 1`
`while (t< 6):`
`  print(t, t, sep = "\t")`
`  t = t + 1`
	t v
	0 0
	1 1
	2 2
	3 3
	4 4
	5 5

Class two: using python to explore graph of a line, slope, x- and y-intercepts

To explore the graph of a line, the slope, and the x- and y-intercepts, students wrote code to build the t,v table representing the ordered pairs that would be graphed. In addition, they used the Python turtle graphics package to draw the equation using the ordered pairs from the table.

The following code was developed with the students to draw the t- and v-axes:

```
import turtle

#DRAW VERTICAL AXIS
turtle.setx(0)
turtle.sety(0)
turtle.goto(0,150)
```

```
turtle.setx(0)
turtle.sety(0)
turtle.goto(0,-150)

#DRAW HORIZONTAL AXIS
turtle.setx(0)
turtle.sety(0)
turtle.goto(150,0)
turtle.setx(0)
turtle.sety(0)
turtle.goto(-150,0)
```

Leaders then guided students through a variety of equations, discussing the slope and the x- and y-intercepts, or more specifically for this project, t- and v-intercepts.

Sample code for exploration of an equation v = 2t:

Code

```
print("t", "v", sep = "\t")
t = 0
while (t< 50):
     print(t, 2* t, sep = "\t")
     turtle.goto(t, 2 * t)
     t = t + 1
```

Output

```
t    v
0    0
1    2
2    4
3    6
4    8
```

The plot produced of the data is a straight line with intercepts at zero (figure 3).

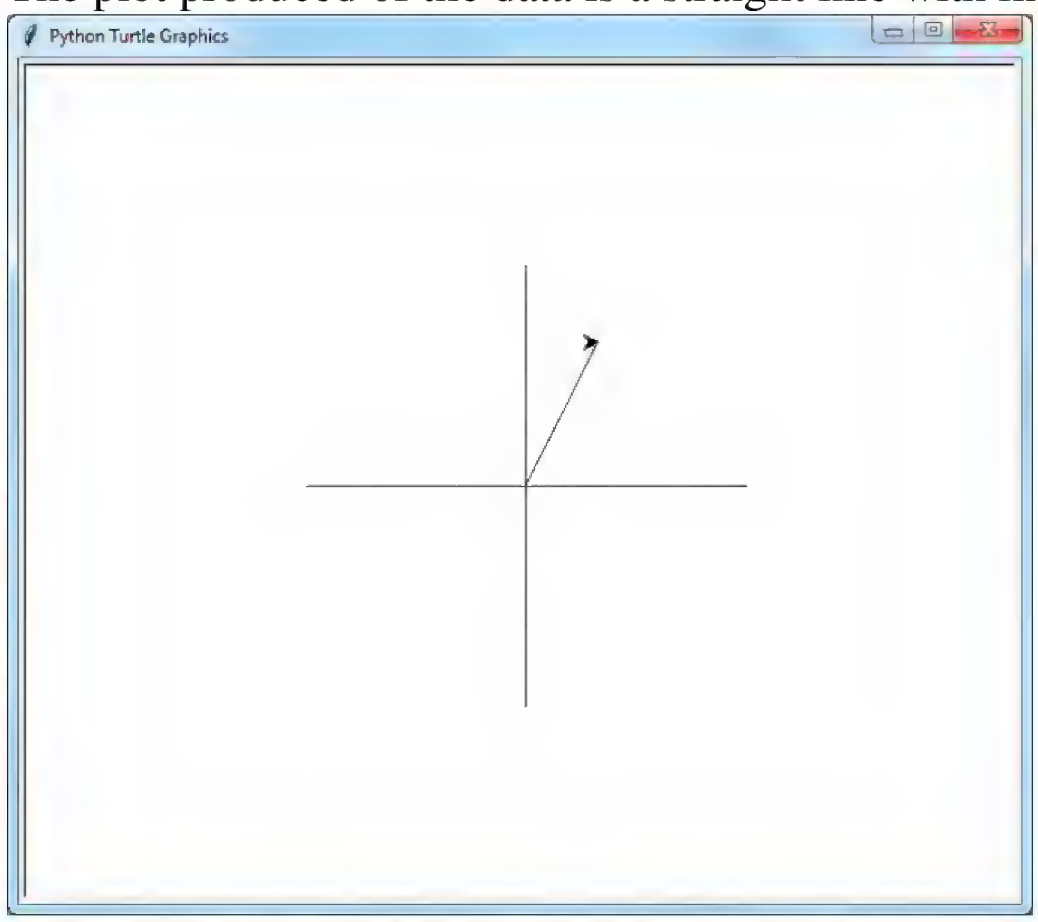


Figure 3. Result of Python code for a straight line with intercepts at (0,0).

Class three: Python Exploration of Line with a negative x-intercept

The next exploration mimicked the function observed for the ice alien, with a negative x-intercept. The sample code for exploration of an equation v = 3t – 16 and its output is:

Code

```
print("t", "v", sep = "\t")
t = -100
while (t< 50):
     print(t, (1/2)* t + 35, sep = "\t")
     turtle.goto(t, (1/2)* t + 35)
     turtle.pendown()
     t = t + 10
```

Output

```
t        v
-100 -15.0
-90  -10.0
-80  -5.0
-70  0.0
-60  5.0
-50  10.0
```

The plot of volume versus time for this equation is shown in figure 4.

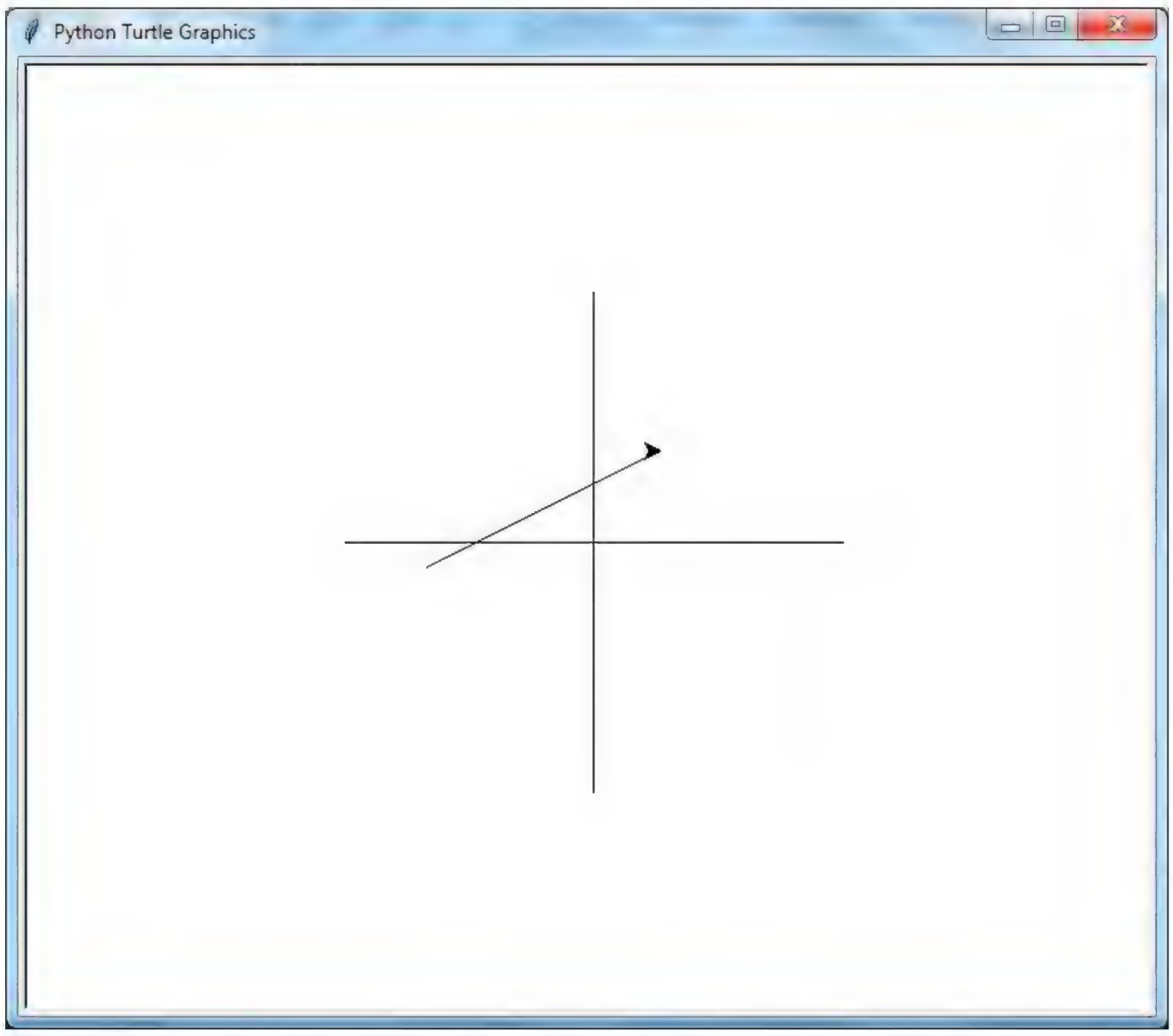
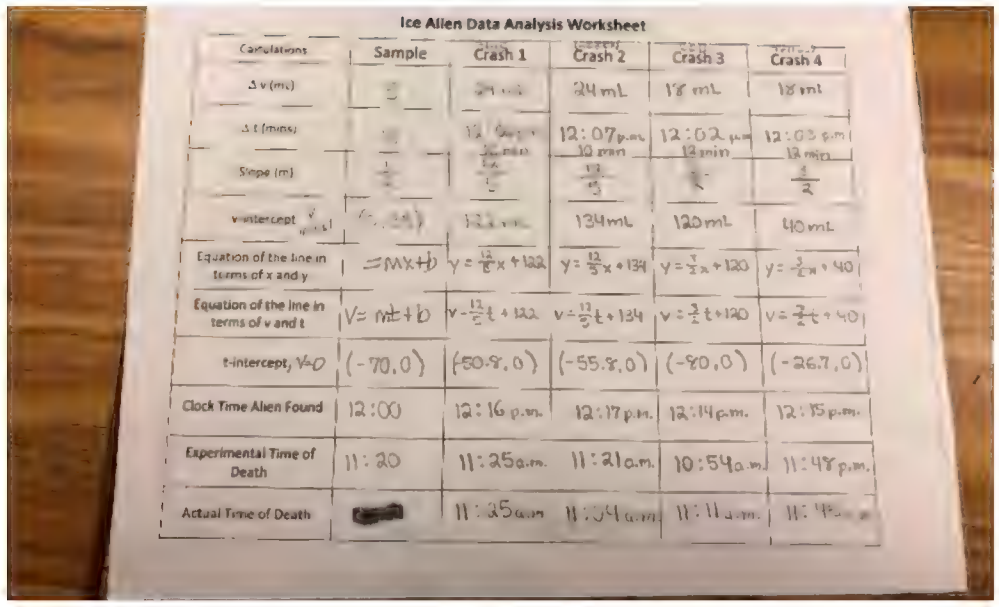


Figure 4. Result of Python code for a straight line with a negative x-intercept.

A mathematical lesson discussing the concepts of slope and negative x-intercepts prepared students for the experiment on the following day.

Class four: The Ice Alien Experiment and Wrap Up

On the day of the Ice Alien experiment, the teacher prepared the crash sites of the aliens as discussed in Section 2.2.1. Students were given data sheets that they used to record their measurements, and determine the time of death of the aliens (figure 5). Each group of students used a graduated cylinder to measure their initial volume of water for each crash site. They then left the room, and different groups measured their initial volume for the crash sites. After all groups made their first measurement, a brief review of the lesson and objectives was done to give time for additional ice to melt. The measuring process was then repeated, giving the students two times and volumes with which, they calculated the time of death of their aliens.


Ice Alien Data Analysis Worksheet

Calculations	Sample	Crash 1	Crash 2	Crash 3	Crash 4
Δ v (mL)			24 mL	18 mL	18 mL
Δ t (mins)			12:07 p.m. − 10 min	12:02 p.m. − 12 min	12:03 p.m. − 13 min
Slope (m)					
v-intercept			134 mL	120 mL	40 mL
Equation of the line in terms of x and y	y = mx + b				
Equation of the line in terms of v and t	V = mt + b				
t-intercept, V=0	(-70, 0)	(-50.8, 0)	(-55.8, 0)	(-80, 0)	(-26.7, 0)
Clock Time Alien Found	12:00	12:16 p.m.	12:17 p.m.	12:14 p.m.	12:15 p.m.
Experimental Time of Death	11:20	11:25 a.m.	11:21 a.m.	10:54 a.m.	11:48 p.m.
Actual Time of Death	[redacted]	11:25 a.m.	11:04 a.m.	11:11 a.m.	

Figure 5. A completed Ice Alien worksheet.

Students first computed the change in time and change in volume to get the slope or rate of change of the volume of melted aliens, and then determined the equation of the line. This allowed them to obtain the x-intercept (time since the crash), with many running the programs they had developed the day prior to explore the x-intercept. The students were able to use the new equation they discovered from the experiment data and analyze the output of the program. The output of the program allowed them to explore where the line of the equation crossed the x-axis through tabular output (t,v table) and graphically (the graph of the line draw by the program). Knowing the time for the first measurement, they then computed the time of the crash. They were then given the actual time the crash happened and compared it against their value. Experience shows the students can get within a few minutes of the actual time of the crash but can sometimes be off by 30 minutes.

Following the experiment, students reviewed the accuracy of their results, and were invited to discuss ways that the experiment might be improved upon and any factors that they thought might have made their results more or less accurate. The experiment was interpreted in terms of how it relates to forensics, the underlying mathematics, and the application of computer science to the problem.

LESSON OUTCOMES

A key outcome for students in this lesson is the demonstration of how physics, mathematics, and computer science are combined to solve a real-world problem. In addition, the physics of melting and phase changes is reinforced, as well as the mathematical concepts of rate of change and linear equations. The application of computer programs to aid in solving this problem completes the full picture of how physics is done.

EVALUATION

The evaluation plan is based on the goals of the transdisciplinary lesson. Although content growth in physics, mathematics, and computer science was measured in the classroom worksheets, the evaluation plan also measured thinking that transcended the content in the separate disciplines. The APOS evaluation scale measures students' work on a problem in a broader, more general sense. It assesses the extent to which the students' work transcends mimicking the instructor or textbook examples to rise to general or even abstract thinking. Scoring was based on the genetic decomposition that hypothesized what a student learning would look like at the Action, Process, or Object level (details below). This method of evaluation is not the focus of this paper, but the interested reader can find more information in Jackson, Jenkins, Jerkins, Stenger, and Terwilliger, 2020 (cite Exploring the Genetic Decomposition paper).

Assessment Items

The research participants for this study were 11 students from a rural high school in Alabama. We used a pre-test/post-test design to assess the impact of the lesson. The pre-tests were administered, before the lesson. The post-tests were administered the following week. The data from the pre-tests and post-tests was scored on two questions, following the APOS (Action-Process-Object-Schema) scale protocol . The two questions were: (1) Given two ordered pairs (20,0) and (24,5), find the equation of the line between the points and calculate the x-intercept for this line, and (2) A candle is burning and the wax is melting in a pan. Assume the temperature of the room stays constant and the height of the candle at 3 hours and 5 hours is 18 inches and 16.5 inches, respectively. Find the rate of change for the height of the candle with respect to time. Write a general expression for the relationship between the height h of the candle and time t. Predict how tall the candle will be after burning for 8 hours. Explain your answer.

Assessment Scoring

Based on the genetic decomposition developed for this lesson, students were rated according to their level of abstraction over the concept. The ratings were assigned by researchers with experience in the APOS scale and training in the genetic decomposition. The assignments were a ranked set of scores to denote pre-Action (0), Action (1), Process (2), and Object (3) levels based on the genetic decomposition (GD). Each score was recorded for each subjects' submission. Three scorers ranked each participant. In the event that authors disagreed, a discussion and further analysis of the data was used to reach consensus. The scoring protocol followed the principled assessment of student learning described in Snow et al. (2017). Students who demonstrated incorrect or missing conceptual development were assigned a score of 0. For example, a student receiving a pre-Action

(0) score may not have calculated the slope correctly in question 1. Students who answered correctly based on memorizing a formula or referring to other outside sources, were assigned a 1. For example, a student at this level might apply the correct formula for slope and show how they plugged in values. Students who demonstrated they imagined a general process taking place, in their imaginations, were assigned a score of 2. For example, the student at this level might have solved 2b correctly. Since ordered pairs are not given in question 2 and term slope is not given (rate of change), correctly completing 2b indicates they imagine the process in their minds. Finally, students who not only imagined a process, but also encapsulated the process into an abstract entity or object, were placed at the object level and assigned a score of 3. For example, the student at this level might have been able to write a correct general expression for the relationship between the height h of the candle and time t, and use it to predict how tall the candle will be. This demonstrates they could apply their knowledge in a novel problem situation, e.g., they can switch x and y with h and t for the independent and dependent variables. This assessment tool is consistent with the objectives of this study since the student, at the highest level, was able to see the concept apart from or above a particular problem or discipline, and they applied abstract reasoning to find a solution to a novel problem. The students who received the highest scores had moved from applying discipline specific formulas (externally motivated), to imagining a process in their minds and using that process to solve a similar problem in a novel environment (process level). At the highest level, they recognized a general behavior and applied it to the new problem to discover a general solution (object level).

Results of Assessment

Approximately 60 teachers and 100 students have participated in the Ice Alien project. The Ice Alien project was first piloted at a regional high school, then at a summer training session for teachers. From there, the teachers took the project to other regional high schools. One of the teachers has completed the Ice Alien Project in two different school years. For both years, at least one team was within 10 minutes of the time of death for all four aliens and in many instances they were exactly on. The second year the data for the present study was collected. The team results are in table 1 below.

Table 1. Student results.

Alien Station	**Actual Time**	**Closest Student Approximation**	
Red	11:11	11:09	Team 1
Blue	11:25	11:25	Team 2, Team 3
Green	11:04	11:08	Team 4
Yellow	11:45	11:45	Team 3

From the table, the results show that the linear method during melting is an excellent approximation for time of death. The students were thrilled to see that they were able to use the tools of math, computer science, and physics together to produce such accurate results.

The pre-test scores showed that 72.73% of the students were at the pre-action level. The post-test scores showed an improvement, as only 45.45% remained at the pre-action level. The pre-post analysis of the tests show that after the lesson, students had developed a better conceptual understanding of the concept of rate of change. In fact, 45.45% of the students improved by at least one level on the APOS scale.

Figure 6 shows the changes in students' pre-test and post-test scores, and figure 10 shows examples of student work.

Despite the overall improvement in understanding of the role of rate of change in estimating time of death of the ice alien and the demonstrated ability of some students to transfer learning to the candle problem, there was still a significant number of students who remained at the action level of understanding.

CONCLUSIONS AND FUTURE RECOMMENDATIONS

In this lesson, we have designed, implemented, and tested a low-risk introduction of a truly transdisciplinary lesson. This lesson has been implemented seamlessly in a high school forensics class, an algebra II class, and a CS Principles class. The lesson can be implemented in a regular classroom without sophisticated materials, (borrowing beakers, etc.)

Using a common scientific and mathematical language, the lesson exploits the physics problem of estimating time of death using rate of change equations, Python programming, and Turtle graphics to explore the mathematical concepts of slope and x-intercept.

Students engage in two different lab environments, first exploring the mathematics in a computing lab, then taking observations of melting "ice aliens" in a physical lab. Students make two observations, recording time and volume, then use their programs or worksheets to determine the graph of the line that models time as the independent variable and volume as the dependent. Next, they estimate the time of death (x-intercept) and interpret the negative value of the x-intercept as it applies to the lab. Students who developed more than an action level (1) of learning were able to apply the skills from this lab to a similar problem.

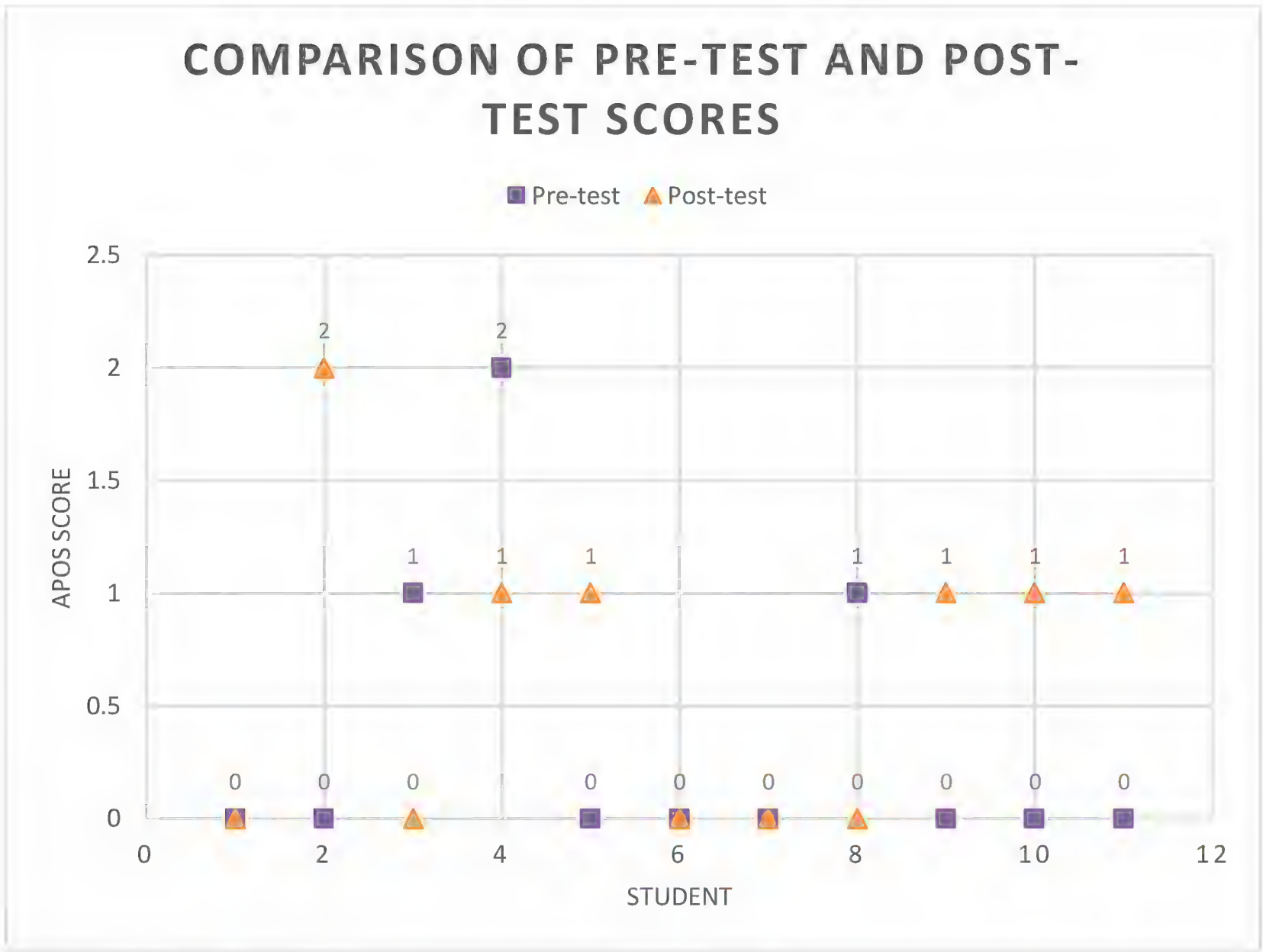


Figure 6. Results of the assessment.

1. Given two ordered pairs (20,0) and (24,5), find the equation of the line between the points and calculate the x intercept for this line.

$\frac{5-0}{24-20} \quad \frac{5}{4} \quad y = \frac{5}{4}x \qquad y = \frac{5}{4}x + 0$

2. A candle is burning and the wax is melting in a pan. Assume the temperature in the room stays constant, and the height of the candle at 3 hours and 5 hours is 18 inches and 16.5 inches, respectively. Find the rate of change for the height of the candle with respect to time.

$\frac{1.5}{1}$ rate of change is 1.5 in per hour

Write a general expression for the relationship between the height h of the candle and time t.

$1.5t = h$

Predict how tall the candle will be after burning for 8 hours. Explain your answer.

$8 \cdot 1.5 =$ 12 in because the rate of change is 1.5 in per hour

Figure 10. Examples of student work.

Students who are able to encapsulate the process of melting ice aliens into an object, may be able to solve the candle problem. The object is to use the exploration and iterative nature of the programming to push students to develop deep transfer of learning and to generalize the process of calculating slope and finding x-intercepts, so that it can be applied in a different setting (candle burning). Most students progressed from pre-action to action level, still relying on formulas for slope and x-intercept. One student did demonstrate a process conception.

For future work, additional assessments for the physics and computer science concepts covered should be created and administered.

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INTERNET USES AND POLITICAL PARTICIPATION IN THE US: A RESOURCES MODEL OVER TIMES

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ABSTRACT

A growing body of literature finds a positive relationship between Internet use and political participation. These studies, however, produce conflicting results. Furthermore, few studies, examine how uses of the Internet influence different forms of political participation over multiple elections. In response, this article argues the Internet is a medium allowing for the development of civic skills through virtual-group membership. We argue not all Internet uses will have the same, if any, effect on specific forms of political participation. After providing findings that Internet use itself does not influence political participation, we develop a resource model to explain how uses of the Internet influence forms of political participation. Following the Civic Voluntarism Model (CVM), and using nationally representative post-election data, we find social uses of the Internet increase the likelihood of individuals to engage in time-based political acts during the 2008 and 2010 elections. These particular uses of the Internet, however, have minimal effects on the likelihood of voting. These findings support the theory that particular uses of the Internet produce a specific set of skills.

Key Words: Political participation, Internet, social media, voting, volunteering, Civic Voluntarism Model

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INTRODUCTION

Did social networking sites (SNSs) influence the outcome of the 2016 U.S. presidential election? While fake news on SNSs influenced voting, SNSs did not affect voter turnout (Curry 2018; Gunther et al. 2018). This research produces a strange picture of SNSs influencing whom we vote for but not influencing if we show up to the polls (c.f. Bond et al. 2012).

Puzzles regarding the influence of SNSs – and the Internet in general – on political behavior are not new. In general, studies find a positive relationship between Internet use and political behaviors (Boulianne 2009; 2015). Research, however, produces inconsistent findings concerning how the Internet influences political behavior over time (Bimber and Copeland 2013; Copeland and Bimber 2015). The puzzle regarding the 2016 election is not a new one. It only adds to an important question: What leads to inconsistent findings concerning internet use and political participation?

This article theorizes that the Internet is a medium where individuals can develop resources that influence their civic and political behaviors. Resource models find that participation in groups produces civic skills (Brady et al. 1995; Verba et al. 1995). These civic skills, however, only increase participation in time-based political acts. Civic skills do not influence other forms of political participation. Following this literature, this article hypothesizes that participation in virtual groups will positively influence engagement in time-based acts while lacking this influence on voting.

To examine the Civic Voluntarism Model (CVM), I use data from the 2008 and 2010 Pew Internet and American Life Post-Election surveys. After showing that Internet use itself does not consistently influence forms of political participation, the article analyzes specific uses of the Internet. The analysis finds that those using SNSs, where virtual groups exist and civic skills develop, are more likely to volunteer but not vote. Over 30 robustness checks, including models with specific SNS actions akin to civic skills, support this finding.

These findings are significant for three reasons. First, this article develops a theory with empirical support that explains inconsistent findings within the literature. While not entirely novel, the theory advances the literature. Second, the Internet and how individuals interact with it are dynamic. To my knowledge, this is one of the few articles using large-N and RDD post-election data from 2008 and 2010 (Bimber and Copeland 2013; Copeland and Bimber 2015; Feezell, Conroy, and Guerrero 2016; Steinberg 2015).[1] This type of data is best to analyze hypotheses concerning internet use and political participation. Furthermore, these years are important to study because they include the social network and smartphone revolutions (Kellogg 2011; Quick 2009; Pew Research Center 2014).[2] These drastic changes provide a fruitful ground

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[1] Large-N and RDD data studies from the 2008 election (Hoffman 2012; Nam and Stromger-Galley 2012) and 2010 elections exist (Feezell 2016). Furthermore, large-N and RDD data from periods before these elections, such as August 2008, exist to study civic and political behaviors (Oser, Hooghe, and Marien 2013; Schlozman, Verba, and Brady 2010; Smith, Schlozman, Verba, and Brady 2009). These studies are valuable, but the latter cannot analyze the proposed theory thoroughly, as they lack data from the complete election cycle. Most importantly, these latter studies cannot compare voting to other political and civic behaviors.

[2] While data in this study are from 2008 and 2010, these data are still appropriate to test the theory. First, the data represent the best source of large-N RDD samples. Boulianne (2009) finds that internet use is less likely to be a significant explanatory variable in RDD samples. Furthermore, few RDD samples exist across elections. Examining multiple elections produces a more demanding test for the hypotheses, as general trends are being questioned instead of election-specific events. The data in this study provides a more challenging test of the hypotheses despite the age of the data. Second, smartphone and SNS use were increasing within the U.S. adult population by 2010. While use is more prevalent today, the data capture a period of acceleration in adopting these technologies. From 2008 to 2010,

for researchers to examine theories that explain the contemporary moment. Finally, the analysis is limited because Pew did not collect data on these questions after 2010. This article provides support for new data collection to examine these topics.

In the following two sections, the article examines the literature. It develops a theory that Internet uses that are analogous to physical behaviors will have similar influences on political behaviors. Two testable hypotheses arise. First, the frequency of Internet use does not have a consistent influence on political behaviors. Second, virtual-group membership increases the likelihood of participating in time-based acts. In the fourth section, I explain the data, variables, and methods utilized in the analysis. The main analysis follows, with a sixth section examining the results of 32 robustness checks. These robustness checks provide evidence that how an individual uses SNSs – not the use alone – fosters engagement in time-based political activity. Finally, the article concludes by discussing the relevance of the findings and directions for future research.

TIME IS NOT OF THE ESSENCE

Initial studies concerning Internet use argue it negatively influences the social bonds necessary for civic and political life by decreasing an individual's time/will to engage in face-to-face interaction (Anderson 2003; Davis 1999; Kraut et al. 1998; Nie and Erbring 2002; Putnam 2000; Winner 2003). These studies theorize that all Internet use has the same influence on behavior. Operationalized as either a binary measure of use/not use or as an ordinal/continuous measure of how much time an individual uses the Internet, these studies find the Internet has a

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smartphone users in the United States increased from 10.3% to 31% of all mobile subscribers, representing about a 200% increase in just two years (Kellogg 2011; Quick 2009). The percentage of U.S. adults with smartphones has increased from about 35% in 2011 to 85% in 2021 (Pew Research Center 2021a). The change in SNS use is even more minor during this period. The percentage of adults using SNSs grew from just under 30% to 60% from 2008 to 2010, according to one study (Pew Research Center 2014). Another study finds the percentage of U.S. adults using SNSs in 2010 was around 46% and is 72% in 2021 (Pew Recent Center 2021b). Growth in the use of Facebook and Twitter is even less dramatic. In 2012, 54% of American adults had used Facebook; this increased to 69% in 2021 (Pew Research Center 2021b). Twitter has seen a slower increase, as 13% of U.S. adults used the platform in 2012 compared to 23% in 2021 (Pew Research Center 2021b). Finally, the time spent on smartphones and social media per day has grown, but the data of this study still capture meaningful engagement with these technologies. In 2014, the average time spent on a smartphone in the U.S. was just over 2.5 hours a day; by 2019, the same population was nearing 4 hours a day on these devices (Wurmser 2019). In 2015, the average U.S. adult spent 66 minutes daily on SNSs, whereas they spend 82 minutes daily on these platforms in April 2020 (Williamson 2020). While smartphones and SNS use have increased in both prevalence and use, the data for this study captures when these technologies were becoming part of everyday life. Finally, the theory and hypotheses in this article test if SNSs affect political behaviors. Due to access and use of SNSs in 2008 and 2010, the hypotheses face a more challenging test from this data. If SNSs influence political behaviors, then data post-2010 evaluate the hypotheses in a more favorable environment as access and use increase. Steger, Williams, and Andolina (2010) find that younger Americans were more likely to engage with politics on SNSs in the 2008 election. Older Americans are more likely to be politically involved. Thus, as these older Americans increased their use of SNSs during the 2010s, the environment for testing the hypotheses becomes friendlier. Indeed, candidates, parties, and organizations are now more likely to use SNSs to engage citizens. For example, Steger, Williams, and Andolina (2010) find that Democrats were more likely to engage in online political activity in 2008. By 2010, Republicans were also using SNSs in a similar method to engage with potential voters (Quintanilla 2011). Throughout the past decade, the politicization of SNSs has increased in numerous manners (see Owen 2019 for a summary). The theory and hypotheses argue that SNSs are a tool that develops skills necessary for time-based political activities. The growth of access, use, and platforms during the 2010s only produces a friendlier environment for the development of civic skills. Thus, the data from 2008 and 2010 produces a demanding test of the hypotheses and theory.

negative influence on civic and political behaviors (Davis 1999; Davis, Elin and Reeher 2002; Kraut et al. 1998; Nie and Erbring 2002; Winner 2003).

The Internet, however, is not a singular force acting on individuals. It is a tool for communication. Why individuals use that tool influences its effect on their political and civic behaviors. That information and communication technologies lack a singular effect on these behaviors is not an old argument. Putnam (1995) provides evidence that watching television reduces them. Norris (1996), however, finds, depending on the content the individual watches, watching television has different influences on behavior. While most television is for entertainment, those using the television for news and current affairs programs are more likely to engage in political and civic behaviors (Norris 1996).

As the relationship between television use and civic engagement is complex, so is the relationship between Internet use and civic engagement. In the 1990s and early 2000s, most Internet users obtained static information focused on entertainment (Littau 2009; Pew 1999). Since most Internet users shared the same experience, early studies using binary or time-based measures of Internet use failed to capture the complex relationship between Internet use and civic engagement. For example, studies that examined those using the Internet to get political information (Tolbert and McNeal 2003) or who developed Internet skills (Weber et al. 2003) find these Internet uses have a positive relationship with civic engagement.

Hypothesis 1: Time spent on the Internet does not consistently and significantly predict civic and political participation.

This hypothesis is not novel, as researchers do examine how specific Internet uses affect civic and political behavior (Bimber and Copeland 2013; Bode 2012; Bode, Vraga, Borah, and Shah 2014; Copeland and Bimber 2015; Feezell 2016; Feezell et al. 2016; Gibson and McAllister 2013; Gil de Zuniga et al. 2010; Hoffman 2012; Kahne et al. 2013; Kittilson and Dalton 2011; Nam and Stromer-Galley 2012; Oser, Hooghe, and Marien 2013; Pasek et al. 2009; Popa et al. 2016; Quintelier and Vissers 2008; Shah et al. 2001; Steinberg 2015; Strandberg 2014; Vissers and Stolle 2014b; Vraga et al. 2015; Yang and DeHart 2016). It is, however, essential to test. The next section argues that some Internet uses develop resources and skills to engage in political behaviors. The theory, therefore, suggests Internet use, as a general experience, does not influence political participation. In order to support this theory, the analysis must first show that time spent on the Internet lacks a consistent relationship with forms of political participation.

CIVIC SKILLS FROM THE DIGITAL TRAINING GROUND

Group membership increases the likelihood of civic and political participation (Ayala 2000; Brady et al. 1995; Hausknecht 1962; Kwak et al. 2004; Lane 1959; Putnam 2000; Teorell 2003; Theiss-Morse and Hibbing 2005; Verba et al. 1995). *Voice and Equality* finds this relationship is due to the resources of civic skills. The CVM argues that active group membership develops civic skills (Verba et al. 1995). Civic skills then increase the likelihood of an individual participating in political acts requiring time and effort while not affecting their likelihood of voting, contributing to political campaigns, or having political discussions (Verba et al. 1995, 358).

Civic skills develop in physical and virtual groups. Virtual groups are groups that primarily exist, communicate, and meet through the Internet. All groups exist to achieve a common goal of their members. Those goals can be to watch the neighborhood for security purposes, perform a religious celebration, or share thoughts about the newest movie. In order for groups to achieve their goals, they require active members. Any active membership in a group leads to the development of civic skills.

For example, a virtual group may want its members to write emails, a civic skill, to save their favorite Netflix show. Some members will need to post messages to communicate their goals and motivate others to act. Posting a message in a virtual group is analogous to the civic skill of giving a speech in a physical group. Both require an individual to express information in a manner to achieve a goal. Even though one may be performed on a keyboard and the other by voice, both members develop civic skills.

As the construction of a community center provides a space for physical groups to meet, platforms allowing individuals to form and join virtual groups, such as SNSs, assist in developing virtual groups.

Hypothesis 2: SNS use increases an individual's likelihood of participating in time-based political activities, such as volunteering for a campaign.

Past studies find a positive and significant relationship between SNS use and time-based acts in online and offline environments (Bod, 2012; Bode et al. 2014; Kahne et al. 2013; Pasek et al. 2009; Vissers and Stolle 2014a; Yang and DeHart 2016). These studies argue that the relationship between SNS use and time-based acts is due to creating norms, developing trust in others, generating social capital, improving political self-efficacy, or group participation in general. The theory of this article argues SNSs increase participation in time-based political acts because SNSs users are more likely to be members of virtual groups, which develops their civic skills.

Although recent studies do not make the theoretical connection between virtual groups and civic skills, their results support this theory (Gil de Zuniga et al. 2010; Ito et al. 2009; Jenkins et al. 2007; Ostman 2012; Strandberg 2014). For example, Gil de Zuniga et al. (2010) defines online expressive participation through an index of those emailing a newspaper or magazine editor, emailing a politician, or signing an online petition. Writing an email to a periodical or politician is analogous to writing a letter, which is a civic skill. The authors define online political messaging through an index of sending a political email to friends or a news story to friends. This measure is similar to Verba et al.'s (1995) operationalization of having political discussions with friends. Finally, Gil de Zuniga et al. (2010) operationalize offline political participation as an index of those who attended a political meeting, rally, or speech; worked for a political candidate or party; or contributed money to a political campaign. Offline political participation, therefore, is mostly measuring time-based acts. The article finds that online expressive participation (i.e., civic skills) increases the likelihood of offline political participation (i.e., time-based acts) while online political messaging (i.e., non-civic skills) has no influence. The resource model theory of this article is consistent with these findings.

Thus, this theory differs from recent literature that examines Internet use and political participation in two important ways (Bimber and Copeland 2013; Bode 2012; Bode et al. 2014; Copeland and Bimber 2015; Feezell et al. 2016; Gibson and McAllister 2013; Gil de Zuniga et al. 2010; Hoffman 2012; Kahne et al. 2013; Pasek et al. 2009; Popa et al. 2016; Steinberg 2015;

Strandberg 2014; Vissers and Stolle 2014a; Vraga et al. 2015; Yang and DeHart 2016). First, some studies create a measure of online political behavior through an index of multiple activities. While these indexes sometimes have high-reliability coefficients, the CVM shows researchers should not combine political behaviors explained by different resources. For example, Hoffman (2012) creates an index measure of online political behavior to test the CVM explicitly. This dependent variable combines the online behaviors of donating money, signing up to volunteer, joining a political group on a SNS, "friending" a candidate on a SNS, and customizing a web page to display political information. The KR-20 reliability score for the variable is 0.58. This score captures the internal consistency of a measure. A score above 0.70 is acceptable; one above 0.80 is preferred, and a score above 0.90 is considered excellent (Wombacher 2018). The theory of this article suggests the reliability score in Hoffman (2012) is below acceptable measures for internal consistency because the index combines political behaviors requiring different resources. Thus, this article offers, at the very least, an accurate test of the CVM.

Second, few studies use large-N RDD data over multiple elections (Bimber and Copeland 2013; Copeland and Bimber 2015; Feezell et al. 2016; Steinberg 2015). While these studies examine if consistent relationships exist across time, there are limitations. Using ANES data, Bimber and Copeland (2013) and Copeland and Bimber (2015) can only test if Internet use to gain information about the election influences forms of political behavior. Steinberg (2015) and Feezell et al. (2016) can produce multiple measures of Internet use but only test if these measures influence voting. Thus, this study differs from these four well-research articles, as it tests if multiple uses of the Internet influences multiple forms of political behavior over time.

METHODOLOGY AND DATA

Pew's 2008 and 2010 Internet & American Life Post-Election Surveys provide the best data to test the hypotheses. The surveys use an RDD process to capture a representative sample of over 2,250 adults across the continental U.S. in both elections (Smith, 2008; Smith and Rainie, 2010). This data allows for a stricter test of the hypotheses, as RDD samples are less likely to find a significant relationship between Internet use and political participation (Boulianne 2009). Data limitations restrict this analysis to 2008 and 2010. Data from 2012-2020 lacks the necessary questions to perform this analysis. This analysis, therefore, serves as a foundation for why data collection on these crucial variables needs to be resumed.

Dependent Variables

Following Verba et al.'s (1995) operationalization, I code political participation into three forms: voting, time-based acts, and political contributions. The dependent variables are dichotomous. I code respondents saying they did not participate as 0 and those who did as 1.

There are important notes about the questions forming the measures of the latter two variables. First, the surveys capture a time-based act by asking if individuals signed up for volunteer activities related to the campaign through the Internet. Individuals that volunteered but did not use the Internet to sign up are not part of this variable. This question is beneficial to test the hypotheses. If an individual develops civic skills in a virtual group, he/she should sign up to volunteer through his/her virtual group on the Internet – not through a physical source. Thus, this dependent variable helps to reduce the endogeneity problem, as it only includes individuals that signed up through the Internet to volunteer. While it does not remove the endogeneity issue of physical-group membership and civic skills developed in physical groups, this does its best to recognize and address the issue. Second, and similarly, the surveys capture political contributions by asking if they donated online for a candidate.

Explanatory Variables

This article uses the frequency of Internet use at home to test the first hypothesis. This variable exists on a seven-point ordinal scale. It exists from 0 (those who never use the Internet at home) to 6 (those who use the Internet several times a day at home).

Virtual-group membership is operationalized through SNS use to test the second hypothesis. Pew asks respondents if they "…ever use the Internet to use a social networking site like MySpace, Facebook or LinkedIn.com." Respondents who never use SNSs are coded as 0. Those who used SNSs but not yesterday are coded as 1. Respondents who used SNSs yesterday are coded as 2.

SNS use is a weak measure of virtual-group membership – and civic skills – for multiple reasons. First, while SNSs host virtual groups, not all users of SNSs engage with virtual groups. Second, the measure does not capture what type of activity and the amount of time an individual engages with their virtual group. The measure cannot separate the virtual group member who is just a member from the organizer of an event. The measure, therefore, cannot distinguish those who have higher levels of civic skills from those with lower levels of civic skills, let alone if SNS use is for virtual groups or other reasons. A weak measure is a strength of this article. If the explanatory variable supports the alternative hypothesis, it suggests an accurate measure of virtual-group membership and civic skills should produce more substantial support of the hypothesis.

While the surveys ask if respondents engage in specific online activities analogous to civic skills, this article uses these measures for robustness checks for three reasons. First, Pew did not ask the question with the same wording in 2008 and 2010. While similar questions exist in both surveys,[3] the change in wording could influence the reliability of the measure. Second, and more importantly, these questions concern individuals engaging in a civic skill for explicitly political reasons. The CVM finds that political interest is a crucial variable in explaining participation. Without a direct control for political interest, using these measures of civic skills could be capturing the effect of political interest instead of civic skills. Finally, the CVM theorizes that all types of groups develop civic skills. While most studies examine if political uses of the Internet influence behavior, results suggest that actions in non-political groups on the Internet promote civic engagement (Kahne et al. 2013). Thus, by operationalizing civic skills through SNS use the explanatory variable tests a weak measure, void of explicit political interest, which the theory argues should support the alternative hypothesis generated by the theory.

Control Variables

The CVM controls for a respondent's level of education, income, age, partisan strength, voter registration, employment status, and religious attendance. The data allows for these controls to be coded and included in the same manner in this analysis. In addition, the analysis incorporates other control variables as proxy measures for missing CVM variables or other possible resources.

The level of trust in government is used as a proxy for political efficacy, which is significant in the CVM. If an individual is a parent is included because a measure of free time does not exist in the Pew data. The CVM finds free time is significant in explaining some behaviors. Parents should have less free time than non-parents. Newspaper reading habits are part of the models because Putnam (1995; 2000) finds reading the newspaper is significant in predicting physical-group membership. Physical groups are an alternative source for the development of civic skills. Since the Pew data does not include a measure of physical-group

[3] These two similar questions are question 26a in the 2008 Pew survey and question 18i in the 2010 Pew survey.

membership, newspaper reading habits are a proxy to help address the endogeneity problem resulting from membership in these groups. Furthermore, newspaper readers are likely to have more political information and interest, other necessary controls lacking in the Pew data (Lee and Wei 2008).

Sex and race are included in the models because the 2008 and 2010 elections made these demographics salient. While the Pew data does not contain questions to measure political interest, past studies utilizing this data use partisan strength to capture political interest (Steinberg 2015). Verba et al. (1995) also find a statistically significant correlation between partisan strength and political interest (348). Finally, the models control for those who use the Internet to get news about the election. Studies find that using the Internet for information can influence political behavior, although these findings are inconsistent over time (Bimber and Copeland 2013; Boulianne 2009; Copeland and Bimber 2015).[4]

Table 1 – Expected Relationship Between Dependent, Explanatory, and Robustness Variables

Variables	*Voting*	*Volunteering*	*Donating*
Internet Use Frequency	Not Significant	Not Significant	Not Significant
SNS Use	Not Significant	Positive	Not Significant
Internet News Use	Positive	Positive	Positive
Political Comment in Online Group (Actualized Internet Use)	Not Significant	Positive	Not Significant
Election Information from SNS	Positive	Positive	Positive
Posted Comment about Election on SNS	Not Significant	Positive	Not Significant
Started or Joined Political Group on SNS	Not Significant	Positive	Not Significant
Dutiful Internet Use	Positive	Not Significant	Positive

[4] See Table S.4 in the Supplemental Appendix shows the results of the probit model with the six-point measure of using the Internet to get news and information about the election. Of the 51 coefficients in the three regressions, there are only four differences between the models. None of these differences influence the explanatory variable. In the model using the three-point measure, a respondent's education level and being an African American are significant at the 95%-level regarding those who used the Internet to volunteer. In the six-point measure model, a respondent's education level does not reach traditional levels of significance; a respondent being an African American reaches the 90%-level of significance with a P-value of 0.067. Full-time employment is also significant at the 90%-level significance in the model concerning donating that uses a three-measure of Internet news, while it reaches the 95%-level of significance in the model for donating that uses a six-point measure. Finally, the coefficient for trust with regards to donating is not significant in either regression, but it is positive in the model using a six-point measure and negative in the model using a three-point measure. With most of the coefficients retaining the same direction and statistical significance across the models, I move forward in the analysis using the three-point measure to produce equivalent models between 2008 and 2010.

Appendix A in the Supplemental Appendix explains the coding of the control variables. Furthermore, Tables S.1 and S.2 in the Supplemental Appendix provide descriptive statistics for all control, explanatory, and robustness check variables. Table 1 provides the expected relationship between the explanatory/robustness check and dependent variables.

Methodology

The analysis uses probit regressions since the dependent variables are dichotomous. As Long (1997) demonstrates, "The choice between the logit and probit models is largely one of convenience and convention, since the substantive results are generally indistinguishable" (83). Logit and probit analyses rest on three assumptions. The only difference between the assumptions of these binary response models is the conditional variance of the error term. Logit models assume the Var ($\varepsilon \mid x$) = 1, whereas probit models assume Var ($\varepsilon \mid x$) = $\pi^2/3$ (Long 1997, 47). These assumptions are arbitrary, cannot be tested, and are necessary for the models (Long 1997, 47). Logit and probit statistical methods do not produce different results with regards to statistical testing. Thus, researchers are free to use either logit or probit methodologies when studying models with a dichotomous dependent variable, as the choice between these statistical methods is a matter of preference.

Three tables of probit regressions form the main analysis. The regressions examine the three dependent variables in two different elections. The first table replicates the CVM using only variables within the Pew data and Verba et al.'s (1995) analysis. This replication shows that the Pew data is appropriate to test the CVM. The second table utilizes the frequency of Internet use to test the first hypothesis. The third table tests the second hypothesis.

The analysis runs five robustness checks concerning the third table. These robustness checks provide additional tests of the hypotheses. The explanatory variables in these checks capture civic skills or were explanatory variables in other studies. However, these explanatory variables provide a more favorable test of the hypotheses as they all concern political activities. Since the Pew data is missing a variable to control for political interest, the explanatory variables in the robustness check are likely to correlate with this attribute. Unable to control for political interest, the main analysis tests the hypotheses in the more demanding setting before proceeding to additional analyses with variables more likely to support the hypotheses.

The value of probit coefficients only provides a variable's directionality and statistical significance (Long, 1997). The analysis uses graphs of the predicted probabilities to provide substantive interpretations of the results.

ANALYSIS

Table 2 - Replication of *Voice and Equality* Table 12.7

Variables	*Voting in 2008*	*Voting in 2010*	*Volunteering in 2008*	*Volunteering in 2010*	*Donating in 2008*	*Donating in 2010*
Education	0.049 (0. 038)	0.137*** (0.028)	0.107* (0.047)	0.096* (0.049)	0.119** (0.041)	0.172*** (0.053)
Family Income	0.086** (0.028)	0.068*** (0.019)	-0.013 (0.032)	-0.005 (0.030)	0.061* (0.023)	0.017 (0.032)
Religious Attendance	0.041 (0.032)		-0.005 (0.036)		-0.065* (0.032)	
Partisan Strength	0.335*** (0.072)	0.159** (0.055)	0.131 (0.108)	0.136 (0.098)	0.166 (0.094)	0.265* (0.112)
Registered to Vote	2.884*** (0.163)	2.935*** (0.243)	0.724 (0.430)	0.311 (0.217)	0.509 (0.336)	0.490 (0.298)
Age	0.008* (0.004)	0.022*** (0.003)	-0.011* (0.005)	-0.005 (0.005)	-0.000 (0.004)	0.004 (0.005)
Full-Time Employment	0.047 (0.163)	0.081 (0.118)	-0.106 (0.190)	-0.344 (0.184)	-0.252 (0.161)	-0.261 (0.184)
Part-Time Employment	0.083 (0.209)	-0.044 (0.150)	0.019 (0.234)	-0.097 (0.226)	-0.246 (0.206)	-0.251 (0.249)
Unemployed	-0.016 (0.207)	-0.031 (0.145)	-0.178 (0.265)	0.099 (0.217)	-0.337 (0.234)	-0.107 (0.243)
Constant	-3.248*** (0.376)	-4.635*** (0.359)	-2.315*** (0.601)	-2.397*** (0.448)	-2.677*** (0.507)	-3.844*** (0.557)
N	1686	1686	986	1276	986	1276
Pseudo R^2	0.5298	0.3963	0.0289	0.0332	0.0429	0.0748

*** = p-value of 0.001 or less (two tail)
** = p-value of 0.01 or less (two tail)
* = p-value of 0.05 or less (two tail)

In general, the replication of the CVM using Pew data produces similar findings to those of Verba et al. (1995). Voting and time-based acts overwhelmingly have the same relationships between explanatory and dependent variables.

Intriguingly, the replication of the CVM for donations deviates from expectations. Income and partisan strength are not statistically significant in explaining donations while education is. This finding could be evidence that political campaigns court physical and online donations differently. Smith et al. (2009b) finds that income has a greater influence on offline

donations than online donations. This article does not investigate this difference. It only notes that the replication of the CVM for online donating deviates from expectations. This article focuses on the political behaviors of voting and volunteering. It reports the results of the regressions for donating, however, for transparency and as a potential source for future research.

The findings from Table 3 support the first hypothesis; frequency of Internet use lacks a consistent relationship with participation. Regarding voting, the frequency of Internet use weakly increases the behavior in 2008 but is insignificant in 2010. While the frequency of Internet use significantly increases the likelihood of volunteering in 2008, it had no significant effect in 2010. General Internet use, therefore, lacks a consistent and significant relationship with participation over time.

Table 4 examines hypothesis 2. The regressions include two types of Internet uses; the primacy of using the Internet to get news about the election and the frequency of SNS use. The results show mixed support regarding political participation and those using the Internet to get information. While Internet news use increases the statistical likelihood of individuals volunteering in 2008 and 2010, it lacks this relationship with voting in both elections. Table 4, therefore, provides mixed support for Boulianne's (2009) findings that using the Internet for information has a positive influence on political participation. Instead, the findings support Bimber and Copeland's (2013) and Copeland and Bimber's (2015) results that show an inconsistent relationship between using the Internet to get information and political participation.

Hypothesis 2, however, tests if virtual groups increase the likelihood of engaging in time-based acts. Remember, as described above, SNS use is a weak measure of membership in virtual groups and an even weaker measure of civic skills. Despite the weakness of the measure, Table 4 supports hypothesis 2, as SNS use significantly increases the likelihood of volunteering in the 2008 and 2010 elections, even when controlling for using the Internet to get information. Furthermore, Table 4 supports hypothesis 2 and the expectations of the CVM, as SNS use does not reach traditional levels of statistical significance as an explanation for voting.

Table 3 - Frequency of Home Internet Use as Poor Measure

Variables	*Voting in 2008*	*Voting in 2010*	*Volunteering in 2008*	*Volunteering in 2010*	*Donating in 2008*	*Donating in 2010*
Frequency of Internet Use	0.070 (0.040)	0.038 (0.030)	0.193*** (0.058)	0.033 (0.045)	0.063 (0.044)	0.090 (0.050)
Education	0.015 (0.052)	0.126*** (0.036)	0.101* (0.051)	0.064 (0.053)	0.124** (0.044)	0.146** (0.057)
Family Income	0.052 (0.037)	0.032 (0.024)	-0.022 (0.035)	-0.007 (0.033)	0.072* (0.032)	0.004 (0.034)
Religious Attendance	0.046 (0.043)		-0.005 (0.039)		-0.053 (0.034)	
Partisan Strength	0.389*** (0.098)	0.189** (0.067)	0.176 (0.118)	0.103 (0.106)	0.162 (0.100)	0.237* (0.117)
Registered to Vote	2.960*** (0.211)	3.121*** (0.380)	0.678 (0.467)	0.269 (0.234)	0.462 (0.351)	0.448 (0.307)
Age	0.013* (0.006)	0.027*** (0.004)	-0.013* (0.005)	-0.004 (0.005)	-0.001 (0.005)	0.006 (0.005)

Full-Time Employment	-0.025 (0.228)	0.000 (0.150)	-0.035 (0.207)	-0.383 (0.199)	-0.279 (0.174)	-0.203 (0.192)
Part-Time Employment	-0.113 (0.286)	-0.112 (0.186)	0.180 (0.253)	-0.037 (0.244)	-0.161 (0.223)	-0.283 (0.267)
Unemployed	-0.136 (0.295)	-0.101 (0.183)	-0.073 (0.285)	0.141 (0.231)	-0.260 (0.247)	-0.069 (0.251)
African American	0.363 (0.316)	0.111 (0.154)	0.394 (0.207)	0.398* (0.192)	0.310 (0.198)	-0.119 (0.248)
Hispanic	-0.101 (0.248)	-0.010 (0.184)	0.425 (0.228)	-0.332 (0.323)	0.220 (0.224)	-0.189 (0.337)
Male	-0.197 (0.149)	0.210* (0.098)	0.155 (0.133)	0.304* (0.135)	0.185 (0.115)	0.198 (0.135)
Parent of a Child	-0.008 (0.149)	0.095 (0.105)	-0.295* (0.138)	-0.152 (0.159)	-0.220 (0.127)	-0.056 (0.164)
Newspaper	0.185 (0.117)	0.155* (0.071)	0.049 (0.103)	-0.106 (0.102)	-0.159 (0.094)	-0.143 (0.100)
Trust	0.121 (0.121)	-0.045 (0.080)	-0.204 (0.116)	0.000 (0.111)	-0.030 (0.099)	0.112 (0.108)
Constant	3.592*** (0.580)	5.045*** (0.532)	3.124*** (0.739)	-2.432*** (0.538)	-3.037*** (0.595)	-4.234*** (0.637)
N	1230	1201	943	1205	943	1205
Pseudo R^2	0.5432	0.3772	0.0853	0.0609	0.0636	0.0872

Note: All variables are coded either as increasing in magnitude or as a dummy-variable
*** = p-value of 0.001 or less (two tail)
** = p-value of 0.01 (two tail)
* = p-value of 0.05 (two tail)

Table 4 – Social Networks and Political Participation

Variables	*Voting in 2008*	*Voting in 2010*	*Volunteering in 2008*	*Volunteering in 2010*	*Donating in 2008*	*Donating in 2010*
Internet News Use	0.109 (0.097)	0.117 (0.072)	0.170* (0.081)	0.198* (0.097)	0.166* (0.071)	0.122 (0.098)
Social Network Use	0.037 (0.104)	0.043 (0.059)	0.233** (0.086)	0.219* (0.088)	0.152 (0.079)	0.113 (0.083)
Education	0.022 (0.052)	0.128*** (0.036)	0.107* (0.051)	0.051 (0.052)	0.123** (0.044)	0.159** (0.055)
Family Income	0.061 (0.036)	0.035 (0.024)	-0.003 (0.034)	-0.003 (0.034)	0.080* (0.032)	0.130 (0.034)
Religious Attendance	0.044 (0.042)		-0.010 (0.039)		-0.053 (0.034)	
Partisan Strength	0.396*** (0.098)	0.201** (0.067)	0.207 (0.121)	0.124 (0.110)	0.179 (0.101)	0.246* (0.118)
Registered to Vote	2.959*** (0.211)	3.133*** (0.381)	0.707 (0.473)	0.260 (0.237)	0.485 (0.357)	0.441 (0.302)
Age	0.013* (0.006)	0.028*** (0.004)	-0.007 (0.006)	0.002 (0.005)	0.004 (0.005)	0.008 (0.006)
Full-Time Employment	-0.090 (0.227)	0.001 (0.150)	-0.090 (0.207)	-0.365 (0.201)	-0.293 (0.175)	-0.210 (0.192)
Part-Time Employment	-0.168 (0.285)	-0.093 (0.186)	0.175 (0.255)	-0.020 (0.248)	-0.146 (0.224)	-0.249 (0.266)
Unemployed	-0.175 (0.295)	-0.082 (0.184)	-0.153 (0.289)	0.177 (0.235)	-0.290 (0.251)	-0.047 (0.251)
African American	0.355 (0.315)	0.129 (0.156)	0.405* (0.204)	0.457* (0.197)	0.317 (0.197)	-0.106 (0.249)
Hispanic	-0.108 (0.248)	-0.037 (0.185)	0.430 (0.225)	-0.336 (0.333)	0.229 (0.224)	-0.200 (0.339)
Male	-0.199 (0.149)	0.202* (0.100)	0.162 (0.133)	0.342* (0.140)	0.173 (0.116)	0.201 (0.137)
Parent of a Child	0.004 (0.149)	0.076 (0.105)	-0.252 (0.140)	-0.196 (0.163)	-0.198 (0.128)	-0.091 (0.165)
Newspaper	0.188 (0.118)	0.172* (0.072)	0.049 (0.106)	-0.057 (0.104)	-0.116 (0.096)	-0.115 (0.101)
Trust	0.135 (0.120)	-0.051 (0.080)	-0.214 (0.116)	-0.030 (0.114)	-0.034 (0.100)	0.105 (0.109)
Constant	-3.447***	-5.083***	-2.915***	-2.882***	-3.256***	-4.162***

	(0.587)	(0.532)	(0.723)	(0.551)	(0.598)	(0.619)
N	1231	1202	944	1206	944	1206
Pseudo R^2	0.5414	0.3816	0.0852	0.0869	0.0741	0.0881

Note: All variables are coded either as increasing in magnitude or as a dummy-variable
*** = p-value of 0.001 or less (two tail)
** = p-value of 0.01 (two tail)
* = p-value of 0.05 (two tail)

Figure 1

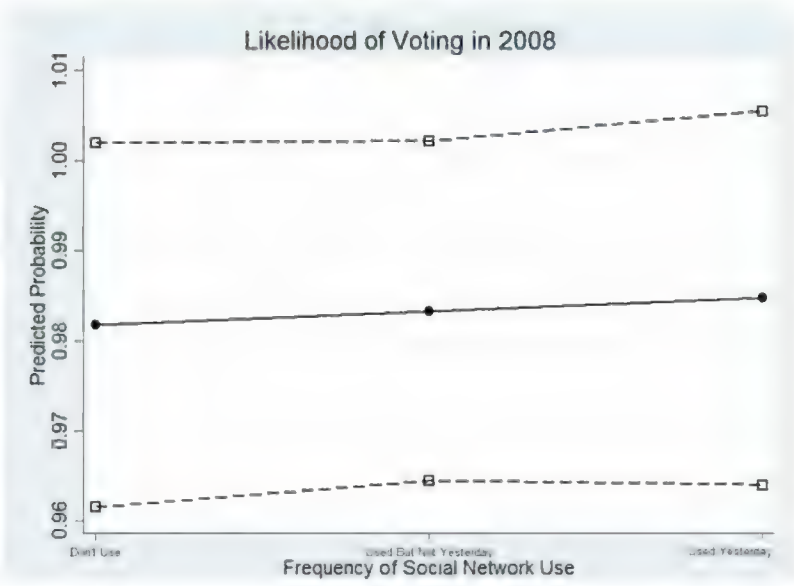


Figure 2

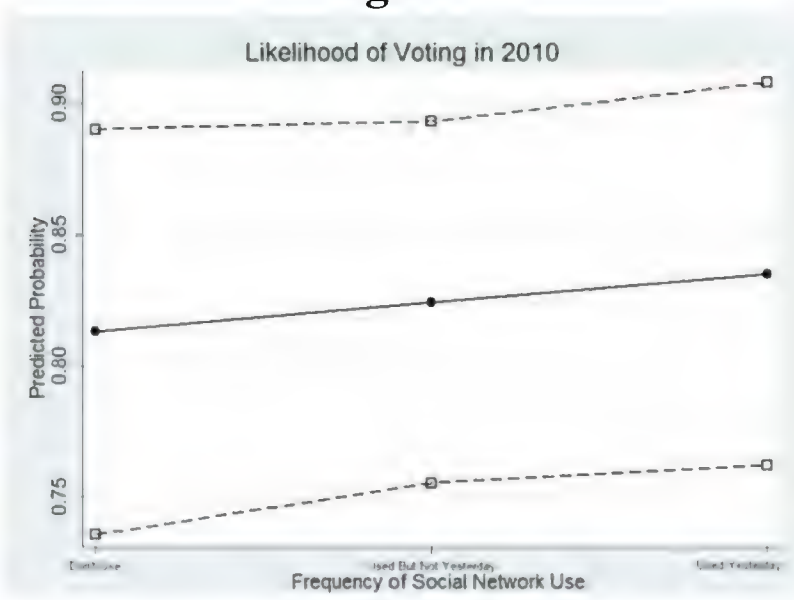


Figure 3

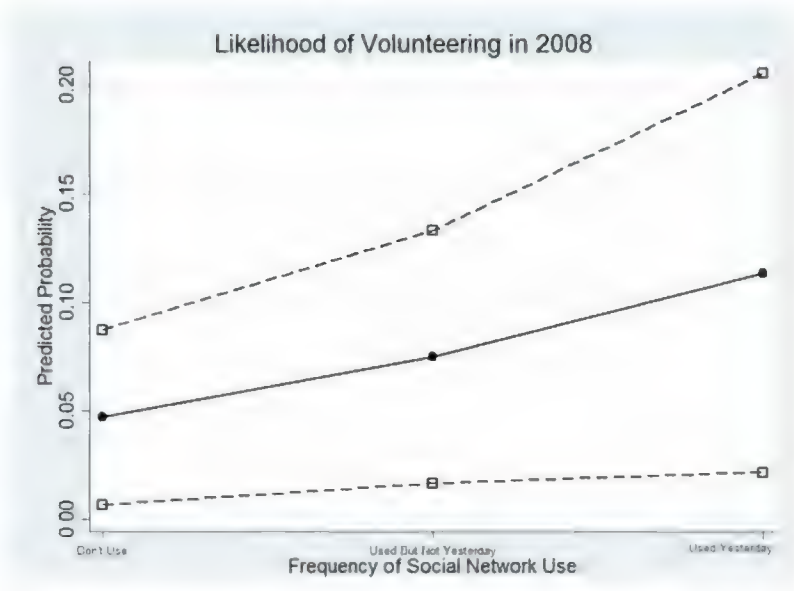
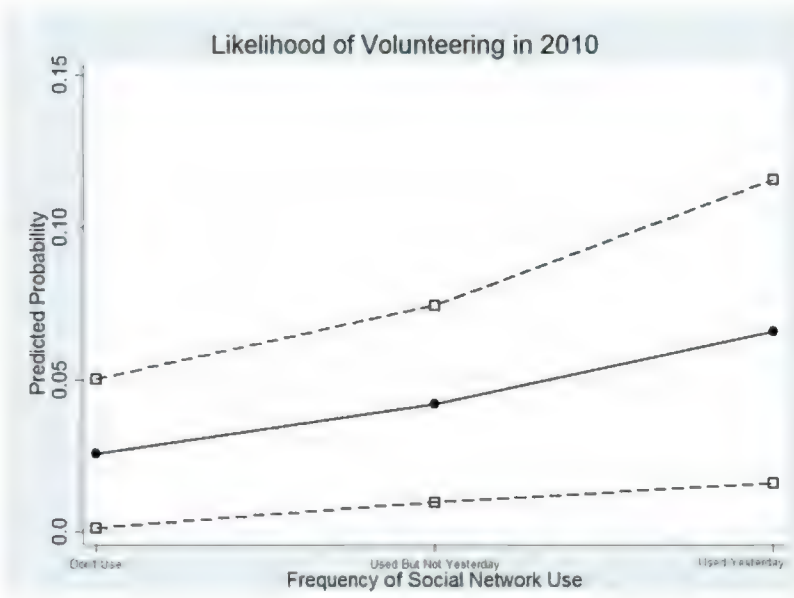


Figure 4



Note: The solid line in the figure represents the average predicted probability. The dotted lines in the figure represent the upper and lower limits of the 95-percent confidence interval.

Figures 1 through 4 provide predicted probabilities to examine the substantive influence of SNS use on political participation. The predicted probabilities hold all the variables, besides the frequency of SNS use, at their median levels. Table S.3, in the Supplemental Appendix, provides these values. The solid lines in the figures represent the average predicted probability, while the dotted lines represent the upper and lower limits of the 95% confidence interval.

Figures 1 and 2 show that an increase in SNS use has no substantive influence on voting. In 2008, the median case that never uses SNS was 98.17% likely to vote, whereas the one that used SNS yesterday was 98.48% likely to vote. Using the same median case, Figures 3 and 4 show that SNS use has a substantive effect on the likelihood to volunteer. In 2008, the median case that never uses SNSs was 4.71% likely to volunteer. The median case who used SNSs yesterday, however, was 11.35% likely to volunteer. Therefore, the use of SNSs increases the probability of signing up to volunteer by over 140%. This change in probability is substantive. While the overall magnitude was not as high in 2010, the effect is similar. Those who used SNSs yesterday are still twice as likely to volunteer than those who do not use SNSs.

To further test the effect of the explanatory variable, predicted probabilities are generated for the case when Internet news use is at its maximum value and all other variables are at their median level. SNS use continues to have a substantive effect on the likelihood to volunteer. In 2008, under these conditions, the likelihood of volunteering increased from 9.11% to 19.25%. In 2010, the likelihood increased from 6.07% to 13.32%. In addition to Figures 3 and 4, these predicted probabilities demonstrate statistically significant and substantive results that support hypothesis 2. Furthermore, Figures 1 and 2 shows that SNS use lacks an effect on voting.

ROBUSTNESS CHECKS

A possible objection is that respondents are not using SNSs for virtual group activities and the development of civic skills. In order to examine this objection, I perform five robustness checks with 32 different regressions. Appendix B in the Supplemental Appendix contains a detailed discussion of the new variables.

The variables used in the robustness check conceptually measure civic skills better than SNS use. The robustness measures, however, are all politically motivated. Political interest is one of the main explanations of political participation. Without direct control for political interest, the robustness measures are more likely to support the second hypothesis due to capturing a respondent's political interest. Thus, the article uses a weaker explanatory variable to provide a more demanding test in the main analysis. While these robustness checks allow for additional tests of the hypotheses, the inability to control for political interest leaves open the possibility that interest in politics instead of the variables of interest are, at least partially, reasonability for any significant findings.

The Pew data allows digital civic skills to be explanatory variables, as preparing a speech for a group is a traditional civic skill. A similar activity for a virtual group member is writing a comment or post to their group. Table S.5 reruns the analysis of Table 4 but replaces SNS use with a dummy variable for those who post comments on an online discussion, listserv, or other online group related to political issues, the campaign, or election. Like Table 4, Table S.5 finds that posting a political comment in an online group has no influence on voting but significantly increases the likelihood of signing up to volunteer. Thus, Table S.5 provides additional evidence of the hypothesis; those practicing a civic skill, even with high levels of political interest, are more likely to volunteer but are not more likely to vote.

The second robustness check examines three specific uses of SNSs and how they influence forms of political participation. These specific uses are individuals getting campaign or candidate information from their SNSs; starting or joining a political group or cause on their SNSs; and posting political comments or questions on their SNSs. The theory predicts that starting or joining a group and posting comments in a virtual group should develop civic skills

that will increase the likelihood of engaging in time-based acts but not voting. Furthermore, it expects information seeking on SNSs not to influence time-based acts.

Table S.6 shows that using SNSs to get information about a campaign or candidates has no statistical influence on an individual's likelihood of voting or volunteering. Furthermore, like Table S.5, posting comments about the campaign or election in a SNS does not influence the likelihood of voting in 2008 or 2010. Posting comments about the campaign or election in a SNS, however, does increase the likelihood of volunteering in 2008. Joining or starting a political group or cause increases an individual's likelihood of volunteering in 2010. Thus, there is some support that online behaviors on SNSs, which are analogous to offline civic skills, increase the likelihood of time-based acts while not influencing voting.

Table S.7 replicates the resource model using the measures of Internet norms employed by Feezell et al. (2016). Table S.5 employs the measure of individuals who commented or posted about political issues as a type of civic skill. Feezell et al. (2016) use this measure as operationalizing citizens who have activated norms. The authors then use Pew's question concerning if individuals look for more information online about candidates' positions or voting records to operationalize citizens with dutiful norms. Feezell et al. (2016) state that one of the study's limitations is that it only examines these measures with regards to voting. Thus, the analysis extends that research.

Like Table S.5, Table S.7 finds that making political posts increases an individual's likelihood to volunteer in 2008 and 2010, but it does not influence if they vote. Those seeking information about candidates' positions or voting records have a greater likelihood of voting and volunteering in the 2010 election. This action, however, does not influence the likelihood of voting and volunteering in 2008. Without data from elections after 2010, it is impossible to know if these information-seeking findings are an anomaly, pattern of midterms, or mark a new behavior. The findings of Table S.7, however, provide additional support for the second hypothesis.

Table S.8 replicates Table S.7 but returns to using SNS use as the explanatory measure of civic skills instead of making a political post. By using those who seek information about candidates' positions or voting records, instead of the primacy of the Internet as a news source, the informational Internet use measure helps as a partial control variable for political interest. As expected, Table S.8 shows that using the Internet to get political information increases the likelihood of all forms of political participation, except voting in 2008. SNS use, however, continues only to increase the likelihood of volunteering. These results provide further support for the second hypothesis, as general SNS use still increases the likelihood of volunteering, even in the presence of a politically motivated online activity.

Finally, the data from 2010 provides an additional measure of a time-based act. The 2010 survey asks respondents if they "Use the Internet to organize or get information about in-person meetings to discuss political issues in the campaign." A similar question does not exist in the 2008 data. Table S.9 reruns the main analysis and the previous four robustness checks with the new dependent variable. The analysis, therefore, tests if the previous models applied only to the time-based act of volunteering or to time-based acts more generally in 2010. Table S.9 finds, in all five models, that the variable(s) that operationalize virtual-group membership or civic skills continue to be significant in increasing the likelihood of engaging in a time-based act. Furthermore, using the Internet for news and SNS to get election information does not significantly influence the likelihood of engaging in time-based acts. While using the Internet to seek information about candidates' positions or voting records (i.e., dutiful norm) does increase

the likelihood of volunteering, this variable correlates with political interest. What is relevant is that SNS use is still significant in explaining another operationalization of the dependent variables, which provides additional evidence of the resource model.

DISCUSSION AND CONCLUSION

This article suggests that the Internet is a medium allowing for multiple uses. Individuals using the Internet to engage in activities that are analogous to offline behaviors will gain similar skills. Thus, members of a virtual group will develop civic skills, which increase the likelihood of participating in time-based acts while not influencing other forms of political participation.

This article first tested if general Internet use consistently explains forms of political behavior to test this theory. Showing that this measure performs inconsistently, the article examines how SNS use influences the likelihood of different forms of political participation. SNSs facilitate virtual groups like a community center facilitates physical groups. Just like a community center, not every user of a SNS will be part of a group. Although a weak measure of virtual-group membership and civic skills, the analysis finds SNS use has a significant and positive relationship with volunteering in multiple elections. At the same time, SNS use lacks a significant influence on voting. Robustness checks with an additional 32 regression models provide additional support for the article's hypothesis. Through examining models that include specific uses of SNSs, an online civic skill, a different measure of using the Internet to get information, and another time-based act as a dependent variable, the robustness checks support that virtual-group membership and digital civic skills increase the likelihood of participating in time-based acts.

While this study provides findings supporting its theory, more work is necessary. First, the theory needs additional testing. Additional tests of this theory require a large-N survey representative of the general population that provides data to replicate the CVM and includes questions regarding uses of the Internet. Questions to gather data regarding political interest, political knowledge, political efficacy, civic skills (both offline and online), and the complete construction of dependent variables, such as time-based acts, are necessary for a more robust analysis.

Second, the data needs to stretch over multiple years to test if the findings are consistent. The Internet is a developing tool. How we use the Internet can change over time. Therefore, data from multiple years will track how technological developments allow an individual to use these tools to engage in political behavior. These developments include how the parties and candidates use the Internet. Steger et al. (2010) find Democrats were more likely to use SNSs in the 2008 election than Republicans. As the Internet changes, one party may be more apt to exploit the opportunities of technology. If the exploitation influences political behavior, such as increasing the number of donations, then the other political party may learn from the past election and embrace the same Internet use in the next election cycle to influence political behavior.

Third, political donations require specific attention, as the findings of this analysis produce a new puzzle for researchers. It is puzzling that the CVM variables existing in Verba et al. (1995) and the Pew data consistently explain voting and signing up to volunteer online, but do not perform in expected manner with online donations. Why are online donations different? Does income better explain physical donations because of the high cost of attending a political banquet, whereas online donations do not require this entry point? These are questions future research needs to examine.

Finally, future studies should collect enough data from each generation – Silent, Baby Boomers, Generation X, Millennials, and Gen Z – to test if generational effects exist. This article tried to perform such an analysis using the Pew 2008 and 2010 surveys. The data, however, contains too few respondents from the Millennials and Gen Z generations to complete the analysis. Additionally, running the regressions with the same variables for each generation proved futile. For example, the analysis uses if a respondent is a parent of a child eighteen or younger as a proxy for free-time – an important control variable for political participation. Respondents in the Silent generation, however, no longer have children under eighteen. Thus, when collecting data to test the article's theory, researchers should also make sure to perform stratified sampling for each generation to test and track generational effects.

While this article does not engage with the research regarding whether the Internet is reinforcing or mobilizing populations to engage in political participation, it theorizes and provides findings that those using the Internet for virtual groups and civic skills are likely to engage in political behavior. While the model cannot include a direct measure of political interest, the inclusion of variables that correlate to political interest – such as partisan strength (Steinberg 2015) – suggests that non-political group activity online can foster political participation (Kahne et al. 2013). Furthermore, the robustness checks, which examine a sub-population of those interested in politics, produce findings that support the main analysis. Furthermore, these robustness checks suggest that civic skills developed and practiced on the Internet influence political participation as predicted by the CVM. Thus, while the article does not inform us if the Internet is mobilizing new individuals to engage in politics or reinforcing the same cleavages, the article does suggest that those who use the Internet in specific ways can develop a particular set of skills they require to participate in civic and political life.

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APPENDIX A: CONTROL VARIABLE CODING

Control Variables for the Civic Voluntarism Model

The first set of control variables capture control variables included in the analyses of the Civic Voluntarism Model (CVM), as created by Verba et al. (1995). These control variables include education, family income, age, partisan strength, if an individual is registered to vote, work status, and church attendance. While the Pew surveys provide a wealth of data, they are missing other important control variables used in the analyses of Verba et al. (1995). These missing control variables include vocabulary, job level, non-political organization, civic skills, political interest, political information, political efficacy, free time, English spoken at home, and Catholic religious preferences.[5] In the next section, I find and explain other control variables to help capture the missing control variables in the CVM. In the current section, however, I explain how I operationalize the Pew surveys to provide data for eight of the eleven important control variables identified by Verba et al.'s analyses (1995).

[5] For an explanation of the construction of all of their control variables, see appendix B of Verba et al.'s (1995).

Both Pew surveys ask respondents, “What is the last grade or class you completed in school?” The responses range on a seven-point scale from 1 to 7. These include "None, or grades 1-8," "High school incomplete (grades 9-11)," "High school graduate (grade 12 or GED certificate)," "Technical, trade or vocational school AFTER high school," "Some college, no 4-year degree (includes associate degree)," "College graduate (B.S., B.A., or other 4-year degree)," and "Post-graduate training/professional school after college (toward a Masters/Ph.D., Law or Medical school." In addition, respondents who said they "Don’t know” or “Refused” have their responses captured. Only 1.51% of the respondents in 2008 and 1.07% of respondents in 2010 said they “Don’t know” or “Refused” to provide their education. These responses, therefore, are dropped from the analysis. Thus, education runs on a 7-point scale, with 1 representing those with an eighth grade or less education and 7 representing those with post-graduate training.

Both Pew surveys use the same question to capture respondents’ income: “Last year, that is in 2007/2009, what was your total family income from all sources, before taxes? Just stop me when I get to the right category…” The responses range on a 9-point scale from 1 to 9. These include, “Less than $10,000,” “$10,000 to under $20,000,” “$20,000 to under $30,000,” “$30,000 to under $40,000,” “$40,000 to under $50,000,” “$50,000 to under $75,000,” “$75,000 to under $100,000,” “$100,000 to under $150,000,” and “$150,000 or more.” Respondents can also answer “Don’t know” or “Refused.” In 2008 and 2010, respectively, 21.21% and 21.49% of respondents answered with “Don’t know or “Refused.” The missing amount of data is alarming, but both surveys retain over 1,770 respondents despite the missing data. I look at the education level of those who do not provide their income level in these surveys to see if those with lesser or greater levels of education are more likely to not respond. Figure S.1 and Figure S.2 show those with a high school education are the most likely not to respond to the question, while those with higher levels of education being the next more likely (although with some greater frequency in 2010). In general, the pattern of who does not respond to the question concerning income is similar in the surveys and shows those who do not respond are spread out over different education levels. When normalizing the number of missing income responses by education level, I find, in 2010, most are between education levels are missing between 18.9% and 22.7% of income responses. Only the two lowest levels of education do not fall in this range, as high school incomplete is missing 31.3% of income responses, and the lowest level of education is missing 37.1% of income responses. These findings were similar in 2008. While the missing data is at a higher rate than desired, especially for the lowest education groups, there does not seem to be a systematic reason for this missing data.

In both surveys, age is coded as a continuous variable from 18 to 96. In addition, all those who are 97 or older are coded as 97. Of the over 4,511 respondents to both surveys, only five are coded as 97. Thus, the collapsing of those older than 97 into a single value does not distort the data in any significant way. Respondents are also allowed to answer “Don’t know” or “Refused” to the question concerning age. In 2008 and 2010, 2.3% and 2.03% of the respondents did not provide their age, respectively. Dropping the respondents who do not provide their age from the analyses does not, therefore, distort the data in any significant manner.

The Pew surveys do not contain a single question measuring partisanship. The surveys, however, ask two questions allowing for the creation of a partisanship variable. First, Pew asks respondents, “In politics today, do you consider yourself a Republican, Democrat, or Independent?” In addition to these three responses, respondents can respond by saying they have “No Preference,” “Other party,” “Don’t know,” or “Refused.” Second, for those who did not answer the previous question with one of the two major parties, Pew asks these respondents, “As

of today do you lean more to the Republican Party or more to the Democratic Party?" In addition, respondents can voluntarily answer the question with "Don't know" or "Refused." Furthermore, in the 2008 survey, respondents can answer the second question with "Neither/Other party" as a voluntary option.

From these two questions, I construct a measure of partisan strength. The measure runs from the weakest partisanship (0) to the stronger partisanship (3). First, I code strong partisans (3) as those who answer the first question by stating they are either a Republican or Democrat. The partisanship strength measure does not differentiate between respondents' political parties. Instead, the measure captures the strength of respondents' attachment to the political parties. As such, those who identify with either political party in the first question are deemed to have the same partisan strength. Next, I examine the second question concerning learners. Those who identify themselves as Republican or Democrat in the leaner question, which excludes those who identified with the parties in the first question, are coded as a leaning partisan (2). To produce a measure of those who are weak partisans or independents, I examine the two questions together. If a respondent said they were an independent in the first question and then said they were neither party, don't know, or refused to answer, I classify the respondent as a weak partisan/independent. The weak partisans/independents are coded as a 1. Finally, I code those who said they had no preference for the political parties in the first question as a 0. Individuals self-reporting to have no preference appear to have no partisan attachments, compared to independents who may still have weak attachments. The construction of the partisan strength variable, therefore, drops respondents who answered the first question by saying they are a member of some other party, don't know, or refused. The dropping of these respondents causes the analyses to lose 5.5% and 6.33% of the respondents to the 2008 and 2010 surveys, respectively.

If an individual is registered to vote is a dichotomous variable, with 1 representing those who are registered and 0 representing those who are not. Both surveys ask respondents, "These days, many people are so busy they can't find time to register to vote, or move around so often they don't get a chance to re-register. Are you NOW registered to vote in your precinct or election district, or haven't you been able to register so far?" While respondents who said, "Don't have to register," "Don't know," and "Refused" are recorded, only 29 respondents between both surveys did not respond to knowing their registration status. These 29 respondents are dropped from the analyses.

To construct a measure for working status, I use the Pew question that asks respondents, "Are you now employed full-time, part-time, retired, or are you not employed for pay?" From this question, I create dummy variables for each response. I use dummy variables instead of an ordinal variable, as each level of employment does not have a definitive linear difference in value from another. As such, it seems safer to proceed with analyses treating each type of working status on its own accord. Each level of employment – unemployed, part-time, and full-time – is made into dummy variables. In addition, the 2010 survey allows respondents to voluntarily say they own a business or are self-employed. These individuals are coded as having a full-time job. The main baseline category for these dummy variables in the regressions is those who are retired. The surveys also allow individuals to voluntarily say they are a "Student," "Disabled," or "Other." While these individuals also exist in the baseline condition, only 13 respondents in 2008 exist in these three categories. In 2010, 109 respondents answered they exist in these three categories compared to 328 retired respondents. Finally, the analyses drop those who refused to provide their employment status, which accounts for 0.58% of the sample in both the 2008 and 2010 data.

The 2008 analyses also include a 6-point scale for church attendance. The 2010 Pew survey does not include a question concerning church attendance. Respondents, in 2008, were asked, "Aside from weddings and funerals, how often do you attend religious services…more than once a week, once a week, once or twice a month, a few times a year, seldom, or never?" In creating a 6-point scale, I reverse Pew's coding, so a 0 represents those who never attend church, whereas a 5 represents those who go to church multiple times a week. The analyses drop the 1.95% of respondents who responded to the question with "Don't know" or "Refused."

Additional Control Variables for the Civic Voluntarism Model

Of the ten CVM control variables missing from my analysis, the most important ones are political information, political interest, and political efficacy. First, I will explain what questions I use from the Pew surveys to capture elements of these missing control variables. After explaining why I include these control variables, I explain the construction of my additional control variables.

The Pew surveys do not ask any questions to directly capture political knowledge and interest in politics. Previous work using the Pew data has used partisan strength to help capture interest in politics (Steinberg 2015). While I include partisan strength, as it is a variable in the CVM, my analyses cannot control for political information and political interest directly. Hoffman (2012), however, went forward with the Pew 2008 data to test if the CVM applies without these direct measures. Furthermore, those analyses are missing other important controls that are in the CVM that I do include, such as being registered to vote. In order to overcome these missing variables, however, I turn to other questions in the Pew surveys to help capture some elements of political interest and information.

With regards to political interest and information, I include dummy variables for African-Americans, Hispanics, newspaper readers, and sex. Given the candidacy of Senator Barack Obama in 2008 and the focus on immigration/DREAM Act, it is likely African-Americans and Hispanics were interested in the election (Carter et al. 2008). Additionally, given the election of President Obama in 2008, it is possible these groups continued to be interested in the 2010 midterm elections compared to the previous midterm election (Lopez 2011). I include newspaper readers to help capture those with more political information, as newspaper readers tend to belong to a great number of groups and are informed (Putnam 1995). By no means is newspaper readership a perfect measure of political information; however, through reading the newspaper, these individuals have access to more political information. Finally, given the presence of Hillary Clinton in the 2008 primaries and Sarah Palin in the 2008 general election, it is possible women had a greater political interest in the presidential election.

Both Pew surveys ask respondents, "Are you, yourself, of Hispanic or Latino origin or descent, such as Mexican, Puerto Rican, Cuban, or some other Latin American background?" The surveys treat the question as a yes or no question, which I code those responding no as 0 and those responding yes as a 1 to form a dummy variable for Hispanics. Only 1.15% and 1.42% of respondents did not share if they were of Hispanic origin in 2008 and 2010, respectively. These nonresponses are dropped from the dataset. Next, the Pew surveys asked respondents, "What is your race? Are you white, black, Asian, or some other race?" Respondents could identify as White, African-American, Asian, Native American, mixed race, other, don't know, or refused. A variable for African-Americans codes respondents who identified themselves as African-American as a 1. Those who do not identify themselves as African-Americans, do not know their race, or refused to answer, are coded as a 0. Nonresponses to the question concerning race caused 2.22% and 3.41% of the respondents to be dropped from the dataset in 2008 and 2010, respectively.

While the dataset could make dummy variables for Asian, Native American, mixed race, and other individuals, it does not. The dataset does not create these dummy variables because there is no expectation for these groups to have a greater political interest in these elections. Also, the percent of the sample identifying in these ethnicities is small compared to the other three ethnicities. In 2008, only 4.83% did not identify as White, African-American, or Hispanic. In 2010, only 7.27% did not identify as White, African-American, or Hispanic. Thus, the analysis uses dummy variables for African-Americans and Hispanics, with all other respondents forming the base category.

To construct respondents' newspaper habits, I utilize a similar question in both Pew surveys: "How have you been getting most of your news about this year's campaigns and elections…from television, from newspapers, from radio, from magazines, or from the Internet?" In addition, the surveys record if a respondent says, "Other," "Don't know," or "Refused." After collecting a respondent's initial news source, the surveys probed for a secondary news source. I code those who said newspapers are not their primary or secondary form of news as 0. Those who said the newspaper is their secondary form of news are coded as 1. Finally, respondents saying newspapers are their primary form of news are coded as 2. Only 1.42% and 2.92% of respondents, in 2008 and 2010, respectively, are dropped from the analyses due to refusing or saying they don't know what their news sources are.

The surveys include respondents' sex by recording their sex as male or female. In both surveys, every respondent provides what sex they are. Thus, I created a dichotomous variable for sex. Respondents who are males are coded as 1, and respondents who are females are coded as 0.

Another important variable missing in the Pew data is political efficacy. While the Pew surveys do not have a precise measure of political efficacy, they do contain a question to help capture political efficacy. Both surveys ask respondents, "How much of the time do you think you can trust the government in Washington to do what is right…just about always, most of the time, or only some of the time?" In addition, Pew captured respondents answering "Never," "Don't know," and "Refused" to the question. While trust is not the same as political efficacy, an individual must have trust in the government to believe the government will respond to their desires and complaints. As such, trust in the government is a precursor to political efficacy. I, therefore, create a 4-point scale for trust in the government. Those who state the government can never be trusted are coded as 0, with those who say the government can just about always be trusted are coded as a 3. Those who did not know or refused to answer the question caused 4.79% and 4.48% of respondents to be dropped from the analyses.

The surveys also do not include a measure of respondents' free time. Both surveys, however, ask, "Are you the parent or guardian of any children under age 18 now living in your household?" Those who are parents are likely to have less free time than those who are without children. As such, I create a dichotomous variable capturing if a respondent is a parent to capture some measure of the amount of free time a respondent has. If a respondent says they are a parent they are coded as a 1, while if a respondent says they are not a parent they are coded as a 0. Only 27 respondents refused to respond to the question or did not know if they were a parent. Thus, these observations are dropped from the analyses.

Although I have done my best to use other control variables to capture variables used by Verba et al. (1995), I cannot find variables in the Pew surveys to capture respondents' vocabulary, job level, if they are a member of a non-political organization, if English is spoken at home, and if they practice Catholicism. Of these five control variables, the CVM only finds vocabulary and job-level to be significant. Furthermore, vocabulary is only significant for voting, and job-level is only

significant for a time-based act. While not being able to include these control variables is a loss, I do not have any reason to suspect the findings of the analysis will greatly differ from those of Verba et al. (1995) due to the exclusion of these five control variables.

Finally, the analysis does not have an exact measure of civic skills. As I have argued in the explanatory variable section, however, social network site (SNS) use provides a weak measure for the development of civic skills. Additionally, I include robustness check models to support the main analysis. These robustness measures look at virtual group membership of writing a post, which is similar to writing a letter, to show how one potential civic skill influences the dependent variables. The robustness checks also examine how specific uses of SNS influence political behavior to further test the theory.

Additional Control Variables due to Findings Concerning Internet Use

The analysis uses two control variables concerning Internet use. The first regards the frequency of Internet use. My theory argues the frequency of Internet use is a poor measure because it fails to account for how specific uses of the Internet influence and develops resources and skills. I create a frequency of Internet use measure to test this hypothesis. To create the measure, I rely on a question asked in both surveys: "About how often do you use the Internet or email from home – several times a day, about once a day, 3-5 days a week, 1-2 days a week, every few weeks, less often or never?" These questions produce a 7-point scale concerning the frequency of Internet use. I code those who never use the Internet as a 0, while those who use the Internet several times are coded as 6 six. A total of 11 respondents either refused to answer the question or responded by saying they don't know how often they use the Internet at home; these respondents are dropped from the analyses.

In the main analysis, I include a control variable for those using the Internet to get information. Multiple studies find using the Internet to get information has a positive effect on political participation (Boulianne 2009; Pasek et al. 2009; Bimber and Copeland 2013). As my theory contends, however, different uses of the Internet will have different effects on political participation. Thus, I control for those using the Internet to get more information to see if virtual group membership and the development of civic skills have an effect on political participation that is separate from those seeking information.

To measure those using the Internet to get information, I utilize the questions in the Pew surveys asking respondents what their primary and secondary news sources for information about the elections. The question regarding news sources is the same question I use to create the newspaper readership control variable. This allows me, therefore, to construct a 3-point scale of Internet use to get news, which is similar to the 3-point scale for newspaper use. Thus, to construct a measure of those who use the Internet to gather information, I code those who use the Internet as their primary source of information as a 2. Those who use the Internet as a secondary source are coded as 1. Finally, those who do not use the Internet as their primary or secondary source of information are coded as 0.

The Pew surveys allow for a more detailed operationalization of Internet use for information in the 2008 survey. That survey asks respondents: "Did you ever go online to get news or information about the 2008 elections? How often did you go online to get news about the elections…more than once a day, every day, three-to-five times per week, one-to-two days per week, or less often?" As such, the question creates a 6-point scale of using the Internet to get news or information. The scale is twice as detailed as the measure created above. I, therefore, create a second measure of Internet use for news and information in 2008. The second measure codes those

who never use the Internet to get news or information as a 0 and increases by 1 for each response, so those who use the Internet more than once a day to get news or information are coded as a 5. This measure is utilized in Table S.4 to provide a robustness check that the 3-point measure of Internet news use is comparable to the 6-point measure of Internet news use.

APPENDIX B: ROBUSTNESS CHECK VARIABLE CODING

Table S.5 introduces a measure for the specific activity of posting in a virtual group. The measure captures an activity akin to writing a speech, which is a civic skill. The measure for posting in a virtual group exists in both Pew surveys, although the question wording and order are different. In 2008, Pew asked respondents, "Have you ever posted comments, queries or information about the campaign or the elections in any of these places online? In an online discussion, a listserv, or other online group forum." Respondents are asked to answer yes or no but could voluntarily respond by saying they don't know or refuse to answer. Of the 1,186 respondents, only two did not answer by saying yes or no. I code those who say they did not post in a virtual group as 0, while those who did post in an online group are coded as 1. It should also be noted that Feezell et al. (2016) use this variable to operationalize active citizen norms.

In 2010, Pew asked respondents, "I'm going to read a list of things you may or may not have done online in the months leading up to the November elections. Just tell me if you happened to do each one, or not: Take part in an online discussion, listserv or other online group forum like a blog, related to political issues or the campaign." Again, respondents are asked to answer yes or no but could voluntarily respond by saying they don't know or refuse to answer. Of the 1,628 respondents, all answered yes or no. I code those who say they did not post in a virtual group as 0, while those who did post in an online group are coded as 1.

Table S.6 introduces three variables to capture the way individuals use SNS. These three measures are using SNS to get information about the election, campaign, or candidates; posting a comment/content about the campaign, and joining or starting a political group or group supporting a clause.

Both surveys ask respondents, "Thinking about what you have done on social networking sides like Facebook and MySpace, have you gotten any campaign or candidate information on these sites?" The question is used to create a variable to see if SNS use influences political behavior due to information uses. In 2008, of the 440 respondents to the question, only two individuals did not answer yes or no. In 2010, of the 925 respondents to the question, only four individuals did not answer yes or no. Thus, I code those who say they did not get information about the election from social networking sites as 0 and those who did as one while dropping those who did not respond with either answer.

Both surveys also ask respondents if they joined or started a group on a social networking site. Group membership and being a leader in a group is an important sign of the development of civic skills. In 2008, Pew asked, "Thinking about what you have done on social networking sides like Facebook and MySpace, have you started or joined a political group, or group supporting a cause on a social networking site?" In 2010, Pew asked this single question as two questions to differentiate between those who join a group and those who start a group. In order to create variables that can be compared, I combine the two questions in the 2010 survey into one measure that matches the question from the 2008 Pew survey. Thus, if an individual joined or started a group, they are coded as a 1; if they did not, they are coded as a 0. Of the 440 individuals who answered the question in 2008, only one respondent did not answer yes or no. In 2010, of the 925 respondents to the question about joining a group, only two did not answer yes. All 925

respondents in 2010 answered yes or no to the question about starting a group or cause. Thus, I drop these three missing observations from the data.

Finally, the Pew surveys capture if individuals posted about the election on SNS. Posting about the election is a behavior similar to the civic skill of writing a speech. Thus, I include this variable in robustness models to examine if political participation is affected by those who develop and practice civic skills in SNS. The 2008 survey asks, "Have you ever posted comments, queries or information about the campaign or the elections in any of these places online? On a social networking site such as Facebook, MySpace or LinkedIn." All 380 respondents to the question answered yes or no. I, therefore, code those who say they did not make a post to a social network site as 0 and those who did as 1. In 2010, the question was changed slightly: "Thinking about what you may have done on social networking sites like Facebook and MySpace related to the November elections, did you happen to… Post content related to politics or the campaign on a social networking site." While not the same, the question is similar to the 2008 survey as it asks if individuals post about the campaign on their SNS. Of the 925 respondents to the question, only one person did not answer yes or no. That one respondent is dropped. I code those who say they did not make a post to a social network site as 0 and those who did as 1.

Table S.7 examines how Feezell et al. (2016)'s variables operationalizing dutiful and active civic norms influence the dependent variable. I argue, however, that these variables capture resources (i.e., civic skills and information). The coding of Feezell et al. (2016)'s active civic norm comes from the same operationalization of posting in a virtual group described in Table S.5. To code dutiful civic norms, which I contend is the resource of information, I follow the authors' coding. Both surveys ask respondents, "I'm going to read a list of things you may or may not have done online in the past year related to the campaign and the elections. Just tell me if you happened to do each one, or not. Did you… Look for more information online about candidates' positions on the issues or voting records." Respondents can answer by saying yes or no, although Pew captures those who voluntarily say they don't know or refuse to answer. In 2008, only two respondents out of 1,186 did not answer yes or no. In 2010, only 1 out of 1,628 did not answer yes or no. These three respondents are dropped from the data set. I code those who say they did not look at information online about candidates' positions or voting records as 0, while those who did as 1.

Finally, Table S.9 introduces and uses a second dependent variable that measures a time-based act in the 2010 election. Pew asks respondents, "I'm going to read a list of things you may or may not have done online in the months leading up to the November elections. Just tell me if you happened to do each one, or not. Did you… Use the Internet to organize or get information about in-person meetings to discuss political issues in the campaign." Of the 1,628 individuals who answer this question, only two did not answer yes or no. These two individuals are dropped from the data set. I code those who did not use the Internet to get information or organize an in-person meeting as a 0, while those who did as a 1.

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Table S.1 – Descriptive Statistics for 2008 Data

Variables	*Observations*	*Mean*	*Standard Deviation*	*Minimum*	*Maximum*	*Context*
Social Network Use	1591	0.407	0.708	0	2	Frequency of Internet use for social networks increases from 0-2
Internet News Use	2222	0.344	0.668	0	2	Use of the Internet for election news with 2 being a primary source, 1 being secondary, and 0 being neither
Internet News (six-point scale)	1585	1.633	1.730	0	5	How often does an individual use the Internet to get election news with 0 being never through 5 being more than once a day
Election Information from SNS	438	0.208	0.406	0	1	Got campaign or candidate information from SNS represented by 1
Posted Comment about Election on SNS	380	0.292	0.455	0	1	Posted comments, queries, or information about the election in SNS represented by 1
Started or Joined Political Group on SNS	439	0.150	0.358	0	1	Started or joined a political group or a cause on SNS represented by 1
Political Comment in Online Group (Actualized Internet Use)	1184	0.086	0.281	0	1	Posted comments, queries, or information about the election in an online discussion, listserv, or other online group form represented by 1
Dutiful Internet Use	1184	0.557	0.497	0	1	Looked for information online about candidates' positions on the issues or voting records represented by 1
Frequency of Internet Use	1,585	4.272	1.792	0	6	Frequency of Internet use at home; increases from never (0) to several times a day (6)
Education	2,220	4.568	1.657	1	7	Level of education increases from 1-7
Family Income	1,776	5.070	2.326	1	9	Level of income increases from 1-9

Religious Attendance	2,210	2.749	1.664	0	5	Frequency of attendance increases from 0-5
Partisan Strength	2,125	2.537	0.696	0	3	Strength of partisanship increases from 0-3
Registered to Vote	2,244	0.895	0.307	0	1	Registered represented by 1
Age	2,202	54.158	17.907	18	97	Continuous variable capturing age
Full-Time Employment	2,241	0.412	0.492	0	1	Full-time employment represented by 1
Part-Time Employment	2,241	0.112	0.316	0	1	Part-time employment represented by 1
Unemployed	2,241	0.119	0.324	0	1	Unemployed represented by 1
African American	2,204	0.103	0.305	0	1	African-American represented by 1
Hispanic	2,228	0.061	0.240	0	1	Hispanic represented by 1
Male	2,254	0.472	0.499	0	1	Male represented by 1
Parent of a Child	2,241	0.276	0.447	0	1	Parent of a child under 18 in their home represented by 1
Newspaper	2,222	0.452	0.684	0	2	Use of the newspaper for election news with 2 being primary source, 1 being secondary, and 0 being neither
Trust	2,146	1.116	0.619	0	3	Level of trust increases from 0-3

Table S.2 – Descriptive Statistics for 2010 Data

Variables	*Observations*	*Mean*	*Standard Deviation*	*Minimum*	*Maximum*	*Context*
Social Network Use	1622	0.911	0.873	0	2	Frequency of Internet use for social networks increases from 0-2
Internet News Use	2191	0.303	0.611	0	2	Use of the Internet for election news with 2 being primary source, 1 being secondary, and 0 being neither
Election Information from SNS	921	0.147	0.354	0	1	Got campaign or candidate information from SNS represented by 1
Posted Comment about Election on SNS	924	0.111	0.315	0	1	Posted comments, queries, or information about the election in SNS represented by 1
Started or Joined Political Group on SNS	925	0.107	0.309	0	1	Started or joined a political group or a cause on SNS represented by 1
Political Comment in Online Group (Actualized Internet Use)	1628	0.057	0.232	0	1	Posted comments, queries, or information about the election in an online discussion, listserv, or other online group form represented by 1
Dutiful Internet Use	1627	0.348	0.477	0	1	Looked for information online about candidates' positions on the issues or voting records represented by 1
Frequency of Internet Use	1623	4.535	1.670	0	6	Frequency of Internet use at home; increases from never (0) to several times a day (6)
Education	2233	4.550	1.657	1	7	Level of education increases from 1-7
Family Income	1772	4.808	2.426	1	9	Level of income increases from 1-9

Partisan Strength	2148	2.444	0.804	0	3	Strength of partisanship increases from 0-3
Registered to Vote	2245	0.820	0.385	0	1	Registered represented by 1
Age	2211	51.538	18.515	18	97	Continuous variable capturing age
Full-Time Employment	2244	0.410	0.492	0	1	Full-time employment represented by 1
Part-Time Employment	2244	0.118	0.322	0	1	Part-time employment represented by 1
Unemployed	2244	0.146	0.353	0	1	Unemployed represented by 1
African American	2196	0.123	0.329	0	1	African-American represented by 1
Hispanic	2225	0.099	0.299	0	1	Hispanic represented by 1
Male	2257	0.436	0.496	0	1	Male represented by 1
Parent of a Child	2243	0.245	0.430	0	1	Parent of a child under 18 in their home represented by 1
Newspaper	2191	0.418	0.697	0	2	Use of the newspaper for election news with 2 being primary source, 1 being secondary, and 0 being neither
Trust	2156	1.151	0.657	0	3	Level of trust increases from 0-3

Table S.3
Median Conditions for Predicated Probabilities

	2008	2010
Education	5	5
Family Income	5	5
Religious Attendance	3	N/A
Partisan Strength	3	3
Registered to Vote	1	1
Age	54	53
Full-Time Employment	0	0
Part-Time Employment	0	0
Unemployed	0	0
African American	0	0
Hispanic	0	0
Male	0	0
Parent of a Child	0	0
Newspaper	0	0
Trust	1	1
Internet News Use	0	0

Table S.4 – Internet News Operationalization and Political Participation Robustness Check

Variables	*Voting in 2008*	*Volunteering in 2008*	*Donating in 2008*
Internet News Use (6-point scale)	0.042 (0.046)	0.177*** (0.042)	0.216*** (0.037)
Social Network Use	0.026 (0.105)	0.187* (0.088)	0.089 (0.081)
Education	0.016 (0.053)	0.073 (0.052)	0.091* (0.045)
Family Income	0.058 (0.037)	-0.017 (0.035)	0.071* (0.033)
Religious Attendance	0.043 (0.042)	-0.001 (0.039)	-0.044 (0.035)
Partisan Strength	0.382*** (0.098)	0.143 (0.121)	0.111 (0.103)
Registered to Vote	2.930*** (0.212)	0.528 (0.447)	0.342 (0.356)
Age	0.013* (0.006)	-0.007 (0.006)	0.004 (0.005)
Full-Time Employment	-0.088 (0.226)	-0.149 (0.218)	-0.378* (0.181)
Part-Time Employment	-0.169 (0.285)	0.172 (0.258)	-0.176 (0.231)
Unemployed	-0.169 (0.294)	-0.169 (0.295)	-0.282 (0.256)
African American	0.346 (0.314)	0.379 (0.207)	0.270 (0.203)
Hispanic	-0.115 (0.248)	0.378 (0.230)	0.238 (0.226)
Male	-0.210 (0.151)	0.102 (0.136)	0.101 (0.120)
Parent of a Child	0.004 (0.149)	-0.243 (0.142)	-0.208 (0.131)
Newspaper	0.166 (0.115)	0.050 (0.104)	-0.118 (0.096)
Trust	0.136 (0.120)	-0.172 (0.119)	0.042 (0.104)
Constant	-3.324*** (0.583)	-2.597*** (0.699)	-3.172*** (0.600)
N	1228	942	942
Pseudo R^2	0.5408	0.1085	0.1173

Note: Unless otherwise noted, in all tables, the variables are coded as either increasing in magnitude or as a dummy variable. Furthermore, all tables use the same markings to indicate significance.
*** = p-value of 0.001 or less (two tail)
** = p-value of 0.01 (two tail)
* = p-value of 0.05 (two tail)

Table S.5 – Online Group Type and Political Participation Robustness Check

Variables	*Voting in 2008*	*Voting in 2010*	*Volunteering in 2008*	*Volunteering in 2010*	*Donating in 2008*	*Donating in 2010*
Internet News Use	0.078 (0.107)	0.127 (0.071)	0.163* (0.083)	0.220* (0.100)	0.146* (0.072)	0.109 (0.103)
Political Comment in Online Group	0.100 (0.264)	0.221 (0.207)	1.102*** (0.165)	1.109*** (0.197)	1.042*** (0.159)	1.181*** (0.205)
Education	-0.140 (0.063)	0.127*** (0.035)	0.092 (0.052)	0.062 (0.054)	0.115** (0.045)	0.161** (0.058)
Family Income	0.023 (0.047)	0.037 (0.024)	-0.011 (0.036)	-0.009 (0.035)	0.078* (0.033)	0.014 (0.036)
Religious Attendance	0.044 (0.050)		-0.013 (0.040)		-0.052 (0.035)	
Partisan Strength	0.389*** (0.119)	0.196** (0.067)	0.256* (0.128)	0.167 (0.116)	0.230* (0.107)	0.256* (0.124)
Registered to Vote	3.093*** (0.304)	3.147*** (0.389)	0.758 (0.530)	0.187 (0.245)	0.479 (0.377)	0.360 (0.311)
Age	0.015* (0.007)	0.028*** (0.004)	-0.009 (0.005)	0.002 (0.005)	0.004 (0.005)	0.010 (0.006)
Full-Time Employment	0.055 (0.264)	-0.000 (0.150)	-0.128 (0.213)	-0.317 (0.206)	-0.329 (0.177)	-0.158 (0.200)
Part-Time Employment	0.013 (0.339)	-0.093 (0.186)	0.149 (0.262)	0.000 (0.259)	-0.196 (0.230)	-0.165 (0.274)
Unemployed	0.077 (0.362)	-0.096 (0.184)	-0.345 (0.306)	0.220 (0.242)	-0.433 (0.260)	0.015 (0.262)
African American	0.466 (0.469)	0.133 (0.155)	0.393 (0.212)	0.483* (0.202)	0.279 (0.203)	-0.062 (0.252)
Hispanic	-0.156 (0.306)	-0.031 (0.185)	0.475* (0.232)	-0.482 (0.356)	0.171 (0.238)	-0.423 (0.393)
Male	-0.258 (0.176)	0.184 (0.099)	0.109 (0.138)	0.248 (0.142)	0.149 (0.119)	0.135 (0.141)
Parent of a Child	0.152 (0.180)	0.077 (0.105)	-0.255 (0.145)	-0.214 (0.169)	-0.172 (0.131)	-0.131 (0.173)
Newspaper	0.082 (0.139)	0.164* (0.072)	0.133 (0.107)	-0.085 (0.108)	-0.081 (0.097)	-0.162 (0.106)
Trust	0.233 (0.149)	-0.040 (0.793)	-0.128 (0.121)	-0.009 (0.115)	0.062 (0.102)	0.165 (0.110)
Constant	-3.387*** (0.688)	-5.056*** (0.529)	-2.957*** (0.771)	-2.777*** (0.556)	-3.457*** (0.615)	-4.316*** (0.643)
N	947	1203	948	1208	948	1208
Pseudo R^2	0.4624	0.3976	0.1519	0.1375	0.1249	0.1513

Table S.6 – Social Network Site (SNS) Behavior and Political Participation Robustness Check

Variables	*Voting in 2008*	*Voting in 2010*	*Volunteering in 2008*	*Volunteering in 2010*	*Donating in 2008*	*Donating in 2010*
Internet News Use	0.476* (0.224)	0.060 (0.086)	0.205 (0.134)	0.074 (0.118)	0.181 (0.124)	0.101 (0.123)
Election Information from SNS	0.060 (0.440)	0.094 (0.211)	0.201 (.0254)	0.188 (0.230)	0.483* (0.245)	-0.218 (0.267)
Posted Comment about Election on SNS	0.128 (0.388)	0.197 (0.213)	0.895*** (0.251)	0.131 (0.246)	0.591* (0.238)	0.495 (0.262)
Started or Joined Political Group on SNS	1.845* (0.885)	0.276 (0.230)	0.455 (0.257)	0.867*** (0.233)	0.213 (0.256)	0.637* (0.261)
Education	-0.149 (0.131)	0.115* (0.048)	0.040 (0.090)	-0.000 (0.065)	0.082 (0.083)	0.127 (0.077)
Family Income	0.048 (0.084)	0.028 (0.031)	-0.058 (0.051)	0.000 (0.042)	0.039 (0.053)	0.024 (0.048)
Religious Attendance	-0.173 (0.103)		0.069 (0.065)		0.016 (0.061)	
Partisan Strength	0.621** (0.231)	0.297*** (0.088)	0.023 (0.203)	0.033 (0.132)	-0.111 (0.168)	0.258 (0.171)
Registered to Vote	3.454*** (0.563)	2.862*** (0.401)	0.637 (0.599)	0.237 (0.283)	0.639 (0.561)	
Age	0.040* (0.16)	0.027*** (0.005)	0.008 (0.009)	0.002 (0.006)	0.022* (0.009)	0.010 (0.007)
Full-Time Employment	0.334 (0.611)	-0.024 (0.210)	0.180 (0.431)	-0.369 (0.256)	-0.229 (0.365)	-0.337 (0.257)
Part-Time Employment	0.229 (0.750)	-0.262 (0.241)	0.649 (0.500)	-0.124 (0.305)	-0.331 (0.468)	-0.412 (0.341)
Unemployed	0.226 (0.725)	-0.143 (0.241)	0.209 (0.528)	0.160 (0.291)	-0.164 (0.476)	-0.564 (0.383)
African American	0.492 (0.607)	0.160 (0.195)	0.458 (0.321)	0.328 (0.250)	-0.234 (0.365)	-0.064 (0.314)
Hispanic	0.428 (0.607)	-0.217 (0.225)	0.269 (0.322)	-0.328 (0.375)	-0.346 (0.390)	0.055 (0.402)
Male	-0.729* (0.348)	0.165 (0.134)	0.170 (0.234)	0.426* (0.172)	0.532* (0.212)	0.202 (0.187)
Parent of a Child	0.392 (0.331)	0.128 (0.121)	-0.618** (0.230)	-0.156 (0.188)	-0.337 (0.206)	-0.126 (0.210)
Newspaper	0.206 (0.280)	0.195* (0.093)	0.130 (0.183)	0.186 (0.125)	0.029 (0.181)	-0.262 (0.152)
Trust	0.552* (0.269)	-0.041 (0.107)	-0.157 (0.197)	-.003 (0.145)	-0.120 (0.184)	0.215 (0.147)
Constant	-5.038*** (1.358)	-4.870*** (0.598)	-2.940** (1.141)	-2.210*** (0.627)	-3.261*** (1.008)	-3.647*** (0.762)
N	315	700	315	703	315	588
Pseudo R^2	0.5483	0.3953	0.2229	0.1531	0.1731	0.1487

NOTE: Registered to Vote is dropped in the 2010 regression for donating because it predicted failure perfectly. This causes 115 observations to be dropped from the regression.

Table S.7 – Feezell et al. (2016) Measures and Political Participation Robustness Check

Variables	*Voting in 2008*	*Voting in 2010*	*Volunteering in 2008*	*Volunteering in 2010*	*Donating in 2008*	*Donating in 2010*
Dutiful Internet Use	0.137 (0.176)	0.559*** (0.109)	0.287 (0.151)	0.741*** (0.157)	0.905*** (0.154)	0.983*** (0.171)
Political Comment in Online Group (Actualized Internet Use)	0.064 (0.267)	0.041 (0.211)	1.050*** (0.168)	0.939*** (0.206)	0.903*** (0.162)	1.013*** (0.213)
Education	-0.019 (0.064)	0.097** (0.036)	0.083 (0.053)	0.034 (0.057)	0.077 (0.047)	0.133* (0.062)
Family Income	0.022 (0.045)	0.033 (0.025)	-0.016 (0.036)	-0.022 (0.036)	0.072* (0.034)	-0.018 (0.038)
Religious Attendance	0.045 (0.050)		-0.012 (0.040)		-0.040 (0.036)	
Partisan Strength	0.381*** (0.119)	0.197** (0.067)	0.231 (0.126)	0.137 (0.120)	0.229* (0.110)	0.318* (0.137)
Registered to Vote	3.050*** (0.307)	3.150*** (0.397)	0.676 (0.531)	0.058 (0.252)	0.243 (0.393)	0.186 (0.333)
Age	0.014* (0.007)	0.028*** (0.004)	-0.009 (0.005)	0.002 (0.005)	0.007 (0.005)	0.013* (0.006)
Full-Time Employment	0.070 (0.264)	0.003 (0.151)	-0.131 (0.212)	-0.387 (0.215)	-0.409* (0.183)	-0.235 (0.214)
Part-Time Employment	0.005 (0.339)	-0.117 (0.188)	0.119 (0.261)	-0.055 (0.264)	-0.284 (0.234)	-0.266 (0.288)
Unemployed	0.084 (0.362)	-0.088 (0.186)	-0.342 (0.305)	0.212 (0.247)	-0.477 (0.268)	-0.056 (0.276)
African American	0.467 (0.466)	0.148 (0.155)	0.403 (0.213)	0.545** (0.206)	0.360^ (0.214)	-0.007 (0.270)
Hispanic	-0.184 (0.308)	-0.030 (0.188)	0.415 (0.231)	-0.468 (0.368)	0.046 (0.246)	0.127 (0.150)
Male	-0.260 (0.177)	0.187 (0.100)	0.118 (0.138)	0.257 (0.147)	0.168 (0.123)	0.127 (0.150)
Parent of a Child	0.153 (0.180)	0.056 (0.106)	-0.235 (0.145)	-0.209 (0.173)	-0.133 (0.135)	-0.152 (0.184)
Newspaper	0.060 (0.134)	0.138 (0.072)	0.085 (0.103)	-0.139 (0.110)	-0.094 (0.096)	-0.178 (0.109)
Trust	0.214 (0.148)	-0.039 (0.080)	-0.136 (0.122)	0.015 (0.120)	0.055 (0.108)	0.191 (0.119)
Constant	-3.295*** (0.679)	-5.017*** (0.532)	-2.769*** (0.760)	-2.675*** (0.562)	-3.649*** (0.643)	-4.623*** (0.687)
N	946	1203	947	1207	947	1207
Pseudo R^2	0.4624	0.3976	0.1516	0.1804	0.1759	0.2334

Table S.8 – Replication of Table S.7 Using SNS Explanatory Variable

Variables	*Voting in 2008*	*Voting in 2010*	*Volunteering in 2008*	*Volunteering in 2010*	*Donating in 2008*	*Donating in 2010*
Dutiful Internet Use	0.131 (0.174)	0.551*** (0.108)	0.445** (0.146)	0.813*** (0.153)	0.983*** (0.151)	1.042*** (0.165)
Social Network Use	-0.046 (0.119)	0.030 (0.059)	0.240** (0.086)	0.196* (0.091)	0.141 (0.081)	0.090 (0.089)
Education	-0.025 (0.064)	0.097** (0.036)	0.089 (0.052)	0.019 (0.055)	0.083 (0.046)	0.123* (0.060)
Family Income	0.015 (0.045)	0.031 (0.025)	-0.010 (0.035)	-0.015 (0.035)	0.075* (0.034)	-0.014 (0.037)
Religious Attendance	0.040 (0.051)		-0.006 (0.039)		-0.040 (0.035)	
Partisan Strength	0.360** (0.120)	0.203** (0.068)	0.186 (0.120)	0.124 (0.116)	0.182 (0.105)	0.307* (0.131)
Registered to Vote	3.058*** (0.306)	3.148*** (0.395)	0.566 (0.479)	0.102 (0.246)	0.183 (0.375)	0.239 (0.326)
Age	0.013 (0.007)	0.028*** (0.004)	-0.006 (0.005)	0.002 (0.006)	0.007 (0.005)	0.011 (0.006)
Full-Time Employment	0.085 (0.266)	0.006 (0.151)	-0.101 (0.208)	-0.439* (0.211)	-0.381* (0.181)	-0.298 (0.207)
Part-Time Employment	0.010 (0.340)	-0.115 (0.188)	0.135 (0.255)	-0.088 (0.257)	-0.241 (0.229)	-0.355 (0.282)
Unemployed	0.089 (0.362)	-0.074 (0.186)	-0.167 (0.290)	0.177 (0.242)	-0.345 (0.261)	-0.122 (0.267)
African American	0.462 (0.464)	0.145 (0.155)	0.434* (0.207)	0.545** (0.204)	0.405 (0.209)	-0.038 (0.269)
Hispanic	-0.200 (0.307)	-0.056 (0.188)	0.363 (0.224)	-0.337 (0.349)	0.077 (0.235)	-0.115 (0.355)
Male	-0.248 (0.177)	0.199* (0.106)	0.171 (0.134)	0.345* (0.145)	0.189 (0.121)	0.191 (0.146)
Parent of a Child	0.170 (0.181)	0.053 (0.106)	-0.217 (0.141)	-0.199 (0.169)	-0.161 (0.133)	-0.110 (0.177)
Newspaper	0.055 (0.134)	0.142* (0.072)	0.011 (0.102)	-0.103 (0.106)	-0.129 (0.095)	-0.136 (0.104)
Trust	0.223 (0.149)	-0.048 (0.080)	-0.223 (0.119)	0.004 (0.120)	-0.035 (0.106)	0.151 (0.118)
Constant	-3.098*** (0.714)	-5.059*** (0.542)	-2.788*** (0.722)	-2.809*** (0.568)	-3.464*** (0.628)	-4.447*** (0.670)
N	942	1201	943	1205	943	1205
Pseudo R^2	0.4644	0.3980	0.0951	0.1473	0.1381	0.1888

Table S.9 – Replication of 2010 Data with Different Time-Based Actions (Use the Internet to Organize In-Person Meeting

Variables	*Meeting*	*Meeting*	*Meeting*	*Meeting*	*Meeting*
SNS Use	0.263***				0.244***
	(0.072)				(0.075)
Internet News Use	0.119	0.034	0.119		
	(0.085)	(0.105)	(0.090)		
Election Information from SNS		0.345			
		(0.195)			
Posted Comment about Election on SNS		0.438*			
		(0.209)			
Started or Joined Political Group on SNS		0.678**			
		(0.214)			
Political Comment in Online Group (Actualized Internet Use)			1.550***	1.390***	
			(0.175)	(0.180)	
Dutiful				0.792***	0.893***
				(0.134)	(0.127)
Education	0.136**	0.073	0.157**	0.132*	0.108*
	(0.047)	(0.059)	(0.050)	(0.053)	(0.050)
Family Income	-0.008	0.001	-0.013	-0.039	-0.032
	(0.029)	(0.037)	(0.031)	(0.032)	(0.031)
Partisan Strength	-0.009	-0.170	-0.024	-0.014	-0.007
	(0.083)	(0.102)	(0.087)	(0.092)	(0.089)
Registered to Vote	0.554*	0.432	0.511	0.411	0.440
	(0.238)	(0.270)	(0.265)	(0.284)	(0.259)
Age	0.005	0.008	0.007	0.009	0.007
	(0.005)	(0.006)	(0.005)	(0.005)	(0.005)
Full-Time Employment	0.101	0.174	0.192	0.181	0.081
	(0.175)	(0.234)	(0.185)	(0.192)	(0.184)
Part-Time Employment	0.122	0.256	0.201	0.173	0.083
	(0.228)	(0.279)	(0.243)	(0.250)	(0.238)
Unemployed	0.251	0.147	0.357	0.336	0.231
	(0.217)	(0.282)	(0.230)	(0.240)	(0.228)
African American	0.407*	0.591**	0.475**	0.550**	0.509**
	(0.172)	(0.203)	(0.178)	(0.188)	(0.182)
Hispanic	0.074	0.257	-0.108	-0.082	0.095
	(0.228)	(0.256)	(0.261)	(0.275)	(0.244)
Male	0.210	0.084	0.110	0.114	0.206

	(0.118)	(0.149)	(0.122)	(0.127)	(0.123)
Parent of a Child	-0.024	0.067	-0.028	-0.047	-0.047
	(0.130)	(0.155)	(0.139)	(0.145)	(0.137)
Newspaper	0.109	0.131	0.073	0.050	0.079
	(0.078)	(0.100)	(0.083)	(0.084)	(0.080)
Trust	-0.078	0.071	0.015	0.011	-0.016
	(0.094)	(0.120)	(0.098)	(0.104)	(0.101)
Constant	-3.430***	-2.775***	-3.501***	-3.559***	-3.520***
	(0.473)	(0.544)	(0.502)	(0.522)	(0.503)
N	1205	702	1207	1206	1204
Pseudo R^2	0.0762	0.1502	0.1758	0.2316	0.1572

Figure S.1

The frequency of those who did not respond how much their family income is by education level in 2008

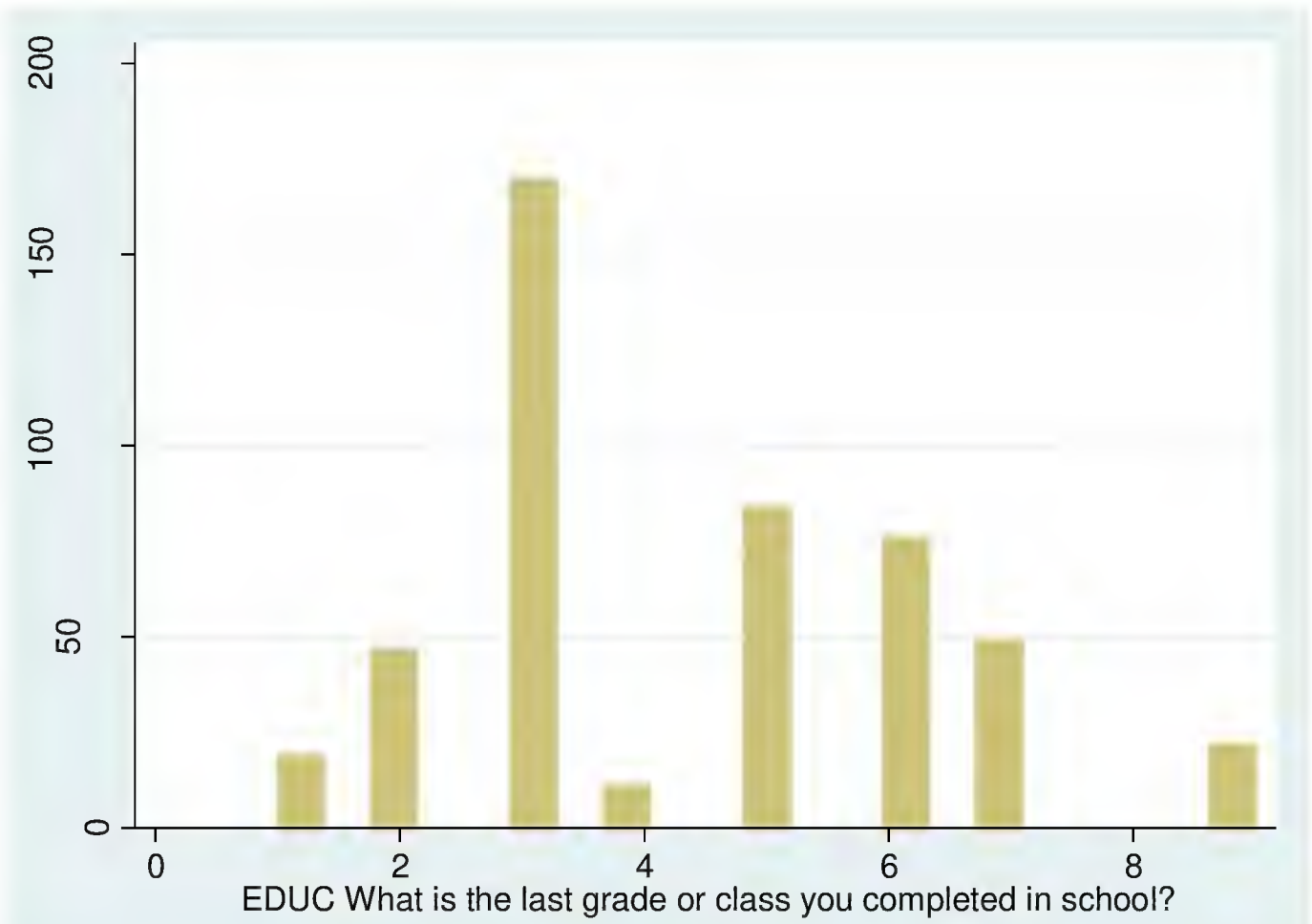
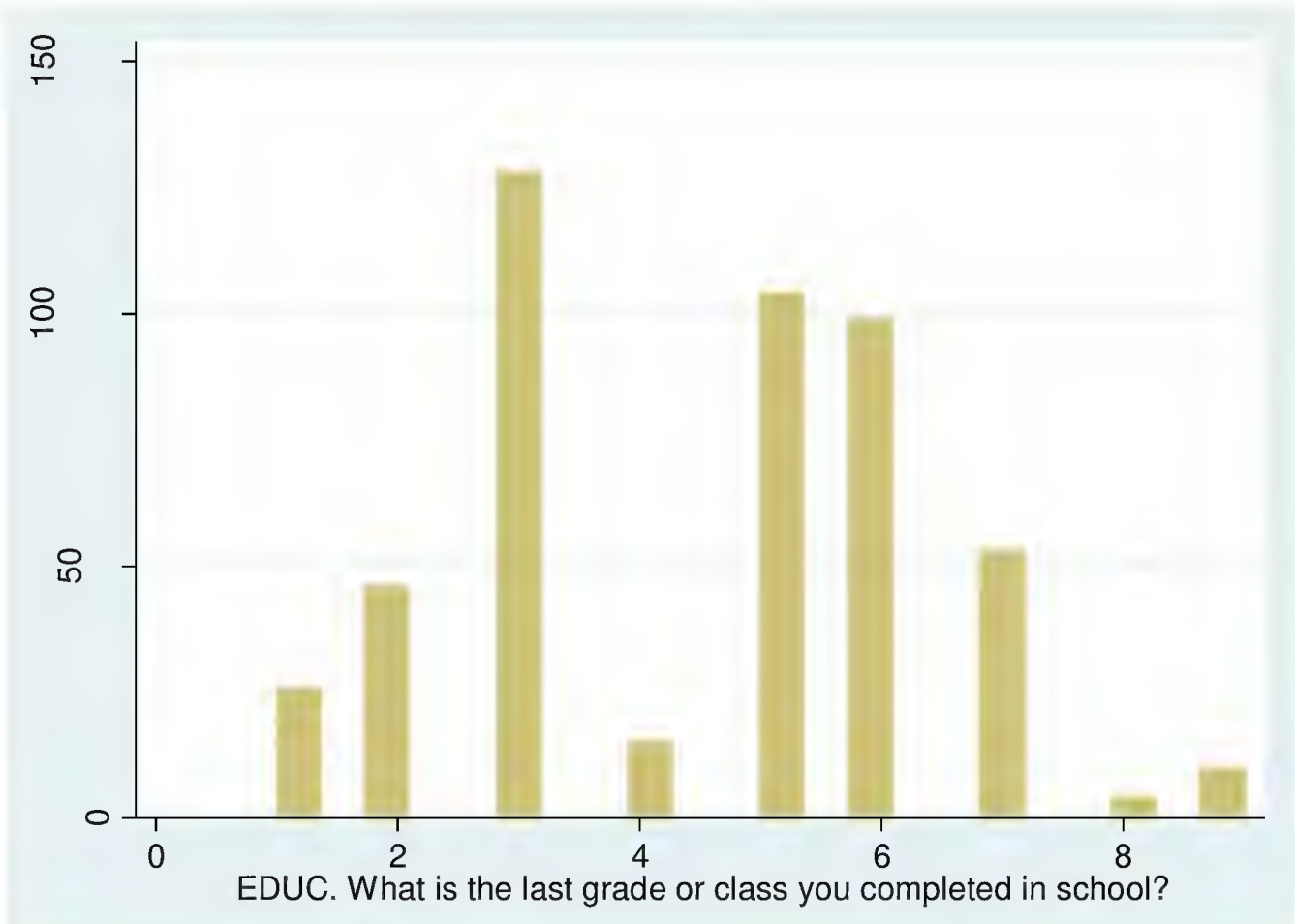


Figure S.2

The frequency of those who did not respond how much their family income is by education level in 2010



MINUTES OF THE
ALABAMA ACADEMY OF SCIENCE
Executive Committee Meeting
Virtual Via Zoom
October 10, 2020

Meeting was called to order at 9:03 am by President, Cameron Gren. Those in attendance were:

Sarah	Adkins-Jablonski
Brad	Bennett
Ellen	Buckner
Brian	Burnes
Donna	Cleveland
Matthew	Edwards
Mary	Ewald
Cameron	Gren
Susan	Herring
Mark	Jones
Larry	Krannich
Akshaya	Kumar
Ken	Marion
Jeff	Morris
David	Nelson
Donna	Perygin
Bettina	Riley
Prakash	Sharma
Jack	Shelley-Tremblay
Vinoy	Thomas
Brian	Toone
Virginia	Vilardi
Wen	Yan

The Minutes from the Spring 2020 meeting were approved.
The following is an update of the Action Items from the Spring Executive Committee meeting.

Action Item	Individuals	Location	Action	Minutes
Approval of the motion regarding procedures and processes to be followed by AAS upon receipt of funds and termination agreement from the Alabama Power Foundation (Appendix A).	Ellen Buckner and Larry Krannich	Appendix A	Approved	Ellen Buckner made a report on the Gorgas Scholarship. Alabama Power Foundation has agreed to transfer control of the scholarship and $300,000 to the AAS. The proposal that has been advanced would involve entrusting the funds to an investment professional in order to generate a goal of 5% interest per year, which should sustain the scholarship competition. Ellen described the motion from the committee (please see Appendix A of the Executive Committee Reports for the details of the motion). The motion was passed unanimously.

Approval of the Motion from the Gorgas Scholarship Committee and AAS Officers [Executive Director, Chair Board of Trustees, President, and Vice President] to approve and sign the AAS / APF Termination Agreement	Ellen Buckner and Larry Krannich	Appendix A	Approved	A second motion to approve the termination agreement with Alabama Power Foundation was presented and unanimously approved.
Approve Treasurer's Report	Bettina Riley	B-6	Approved	Motion by David Nelson. Second from Donna Cleveland
Approve Finance Committee Report	Ken Marion	C-2	Approved	Motion by Jack Shelley-Tremblay. Second from David Nelson
Long-term path forward for JAAS	Brian Toone and Jack Shelley-Tremblay	B-7 and C-18	Approved	Brian Toone presented a summary of the current stae of the journal. It is being published in an online format currently. We are faced with the question of whether we want the journal to be a revenue generator with a subsctiption-only access model or whether we want the readership to be as wide as possible and access to be open. These two options are presented in the Journal Editor's Report. There is some annual cost associated with the indexing process. We need to pay for a journal DOI, which will allow us to generate article DOIs. Adding a page charge to publications that would be paid by authors was discussed as a possible mechanism to cover the cost of the DOI. Cameron Gren moved that the academy funds the DOI fee and continue open access. Prakash Sharma seconded. The motion passed unanimously.
AAS hosting the virtual State Science Fair	Virginia Vilardi	B-9	Approved.	Many science fairs have not finalized plans yet. Some fairs have cancelled entirely for this year, including the state fair (which would have been April 9). The International competition is going to be virtual. There was discussion of the Academy hosting these fairs digitally. Jack Shelley-Tremblay moved to host the science fair meetings, and Virginia Vilardi seconded. The motion passed unanimously.

Creation of a virtual store	Sarah Adkins-Jablonski and Jack Shelley-Tremblay	B-12, VII	Approved.	The shop in the website has been created, although no items are available for sale yet. A batch of vinyl durable stickers with the AAS logo have been printed. They cost about 7 cents to produce and $0.55 to ship. Jack Shelley-Tremblay moved to charge $1.45 per small sticker and $0.55 for shipping. Cameron Gren amended the motion to authorize Sarah Adkins-Jablonski and Jack Shelley-Tremblay to post items for sale on the website for a reasonable price. Donna Cleveland seconded. The motion passed.
Approve Registration Form and Fees for 98th annual meeting	Larry Krannich	B-13, Appendix B	Approved.	Larry Krannich moved to approve the registration form and Prakash Sharma seconded. The motion passed.
Approve Call for Papers for 98th annual meeting	Larry Krannich	B-13, Appendix C	Approved.	Larry Krannich moved to approve the call for papers (with the correction of removing the hard copy journal option at the end of the document) and Prakash Sharma seconded. The motion passed.
Vote to shift to a renewal model or make no change to the current JAAS subscription model.	Jack Shelley-Tremblay	C-18	Tabled.	Estimated costs to the Academy of supporting the journal in an open access form are $550 per year. Jack Shelley-Tremblay described an option that we continue to offer subscriptions to individuals or institutions who subscribe to our journal annually. A 12 month embargo was also discussed, where only subscribers and Academy members can view this year's journal, and all previous issues are open access. This motion was tabled until the Fall 2021 meeting.
Vote to continue the current $100/article charge for the JAAS subscription or convert to Open Access.	Jack Shelley-Tremblay	C-18	Approved	Jack Shelley-Tremblay moved to remove page charges to authors for publication in the AAS Journal. Brian Toone Seconded. The motion passed.

Action Items from Fall 2020 Executive Committee Meeting			
Action Item	**Person Responsible**	**Due Date**	**Action**
Vote to shift to a renewal model or make no change to the current JAAS subscription model.	Jack Shelley-Tremblay	Fall 2021	
Proposal to create and sell merchandise in the online store.	Jack Shelley-Tremblay and Sarah Adkins-Jablonsky	Spring 2021	

The Alabama Science Trail Committee offered a report on their two recent meetings, where they created a featured list of outdoor sites and to discuss a collaboration with Mark Jones in the Junior Academy. He has received a $7000 grant from the Army Education Fund to develop the Science Trail. He will be visiting 10-20 sites this year and developing resources, contacts, and websites about them. A motion was proposed by Ellen Buckner to purchase the domains alabamasciencetrail.com and alabamasciencetrail.org in order to host the Albama Science Trail website. The motion was passed unanimously.

The Committee and Section Reports were reviewed. Notes as follows:

The Local Arrangements Committee report delivered verbally by Jack Shelley-Tremblay indicated that the meeting will take place in Zoom meeting rooms and virtual poster sessions viewable by attendees and judges. A single meeting link will take attendees to a list of Zoom rooms by section. There will be a host for each Zoom meeting. There will be zoom rooms for section meetings, as well.

As an extension of the AJAS report, Mark Jones proposed that the 11 local competitions would pre-screen competetiors for the regional meeting's 25 spots.

The meeting date will be changed to a later date (March 17-19) to permit more time for students to prepare for competitions.

Jack Shelley-Tremblay moved that the treasurer be authorized to reimburse Sarah Adkins-Jablonsky for the cost of the merchandise that she ordered. Akshaya Kumar seconded the motion. The motion passed.

The Committee on Science, Public Policy, and Public Relations needs additional members. Matthew Edwards and Mark Jones volunteered.

Prakash Sharma suggested that we formally present the Gardner awards and Fellows with their awards. Ellen Buckner suggested a post on the website to publicize the awards.

The meeting adjourned at 11:35 AM.

Alabama Academy of Science Journal

Scope of the Journal:

The Alabama Academy of Science publishes significant, innovative research of interest to a wide audience of scientists in all areas. Papers should have a broad appeal, and particularly welcome will be studies that break new ground or advance our scientific understanding.

Information for the Authors:

- Manuscript layout should follow the specific guidelines of the journal.
- The authors are encouraged to contact the editor (E-mail: brtoone@samford.edu) prior to paper submission to obtain the guidelines for the author.
- At least one author must be a member of the *Alabama Academy of Science* (except for Special Papers).
- The author(s) should provide the names and addresses of at least two potential reviewers.
- Assemble the manuscript in the following order: Title Page, Abstract Page, Text, Brief acknowledgments (if needed), Literature Cited, Figure Legends, Tables, Figures.

Review Procedure and Policy:

Manuscripts will be reviewed by experts in the research area. Manuscripts receiving favorable reviews will be tentatively accepted. Copies of the reviewers' comments (and reviewer-annotated files of the manuscript, if any) will be returned to the correspondent author for any necessary revisions. The final revision and electronic copy are then submitted to the *Alabama Academy of Science Journal* Editor. The author is required to pay $100 for partial coverage of printing costs of the article.